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Cultivating climate change resilience in agri-food systems:

Responses to natural disasters and emerging climate risks in Queensland's fresh produce supply chains

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Abstract

Over the last decade, Australia has experienced several severe natural disasters which have caused significant disruptions to its agri-food supply chains. Global climate change is driving an increase in the frequency and intensity of extreme weather events that can lead to natural disasters. The Intergovernmental Panel on Climate Change (IPCC) warns that climate change - and extreme weather events, in particular - pose significant threats to food security. While much food security research focusses on developing nations, contemporary, supermarket-based food systems have a number of characteristics that make them highly vulnerable to disruptions from extreme weather events. The experience of recent disasters and projections of on-going climate change suggest that Australia's food systems are facing escalating climate risks to which they must adapt.

This thesis considers how the agri-food supply chains that underpin Australia's food system are enabled or constrained to cope with emerging climate risks and, in particular, to a more rapid recurrence of damaging weather events. In this thesis, supply chains are conceptualized as social institutions and identified as a key location in the food system for decision-making regarding the management of climate risks. The empirical focus of the research is national-scale fresh produce supply chains based on vegetables produced in south-east Queensland's Lockyer and Fassifern Valleys. These supply chains have been affected by a series of severe weather events and natural disasters since 2011. The study applies qualitative methods to draw insights from supply chain actors regarding: the impacts of recent severe weather events; perceptions of these events and future climate risks; the ways in which climate risks are governed in the supply chain; and what responses have occurred following recent events. The analysis is informed by theoretical perspectives from the social sciences, in particular the social construction of risk, risk governance and resilience. The thesis aims to advance recent conceptualisations of food system resilience and proposes a set of attributes that would enable a capacity for resilience to climate risks and natural disasters within agri-food supply chains.

The results of the study demonstrate that the impacts of recent natural disasters were unevenly distributed within the supply chain. Upstream segments of the chain (that is, business involved in vegetable production, packing and transport) experienced more significant impacts and longer recovery periods than downstream segments (such as wholesalers and retailers). The study finds that this is strongly linked to an uneven distribution of vulnerability to risks in the chain which, combined with the rapid recurrence of disaster events, has weakened the fresh produce supply system.

The study provides important insights into perceptions, and social constructions, of recent weather events and climate risks amongst actors within fresh produce supply chains – addressing a significant gap in the literature. The results suggest that a shared narrative about Australia's highly variable climate strongly influences a collective construction amongst supply chain actors which normalises and attenuates climate risk. The study finds, however, that recent extreme weather events have unsettled this dominant construct. Perceptions of future climate risks amongst supply chain actors were varied. Those strongly influenced by the climate variability narrative did not expect future risks to be much different from those experienced in the past. A smaller number of research participants, however, were concerned that climate risks may be escalating and that this may require changes to how those risks were managed.

The study found two strongly contrasting approaches to the governance of climate risk in fresh produce supply chains. The findings demonstrate that, typically, climate risks are governed in highly individualised ways but that the emergence of new supply chain intermediaries is facilitating a more collective approach to climate risk governance in some chains. The research also shows that recent recurrent floods have catalysed a number of supply chain actors to pursue changes that improve their capacity to more effectively manage climate risks. Those most motivated to make adaptations were found to be involved in supply chains characterised by individualised governance of climate risks.

The thesis concludes by considering what the findings suggest about the prospects for cultivating resilience to escalating climate risks in supply chains and the implications for food security in Australia. The study finds that while a collaborative approach to risk governance is emerging in some cases, there are significant constraints to cultivating climate change resilience in fresh produce supply chains in Australia – and that this adds to known threats to our national food security. The research suggests, however, that adopting a risk governance perspective could help to engage a wider set of social actors, particularly governments and consumers, in the process of improving supply chain and food system resilience in the face of climate change.

Declaration by author

This thesis **is composed of my original work, and contains** no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my research higher degree candidature and does not include a substantial part of work that has been submitted **to qualify for the award of any** other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

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Publications during candidature

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Keywords

Agri-food, food security, climate change, resilience, risk governance, supply chain

Australian and New Zealand Standard Research Classifications (ANZSRC)

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ANZSRC code: 160804, Rural Sociology, 45%

ANZSRC code: 150309, Logistics and supply chain management, 10%

Fields of Research (FoR) Classification

FoR code: 1608, Sociology, 90%

FoR code: 1503, Business and management, 10%

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List of abbreviations

ACCC	Australian Competition & Consumer Commission
BoM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFF	Queensland Government Department of Agriculture, Fisheries and Forestry
DEEDI	Queensland Government Department of Employment, Economic Development and Innovation
FAO	Food and Agriculture Organisation of the United Nations
IPCC	Intergovernmental Panel on Climate Change
NHMRC	National Health and Medical Research Council
PMSEIC	Prime Minister's Science, Engineering and Innovation Council
QFF	Queensland Farmers' Federation

Chapter One: Contemporary fresh food systems in a changing climate

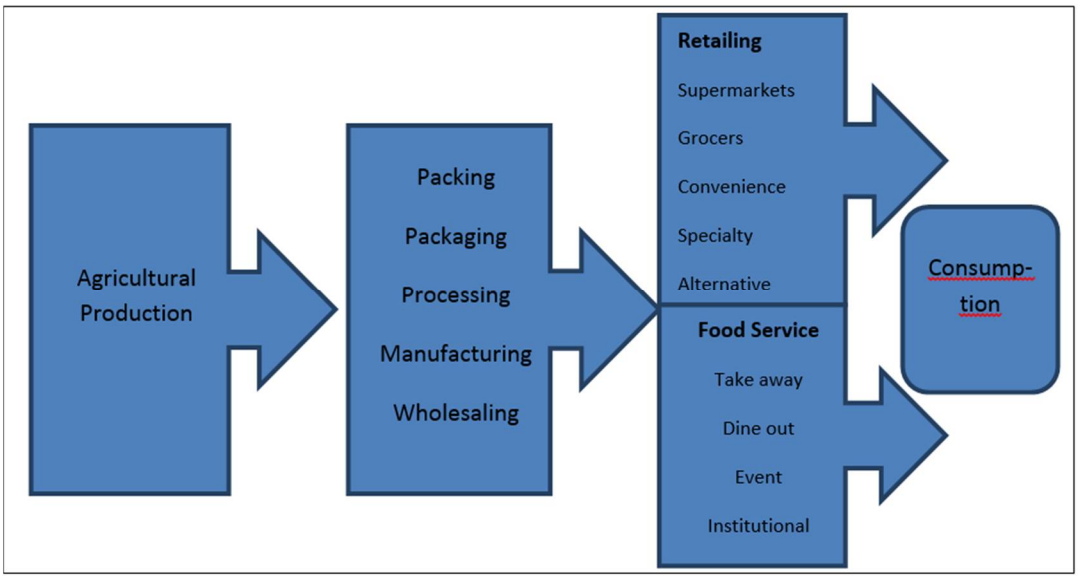
> "Food systems are the foundation of human health and wellbeing, so understanding and managing the weaknesses and vulnerabilities within complex food systems is essential to society."
>
> Keating, 2013, p. 21

Introduction

Most Australians enjoy easy access to a plentiful and diverse supply of affordable fresh food – which is largely supplied by domestic producers. Australia's food system (Figure 1.1) is based predominantly on supermarkets and the food services sector along with online grocery ordering and delivery services, independent grocers, specialist food stores and convenience stores (Spencer and Kneebone, 2012). 'Alternative food networks' (such as farmers markets) that seek to more closely connect food producers and consumers and encourage fair trade also operate within the system (Andrée et al., 2010, Australian Farmers' Markets Association, 2014, Tregear, 2011). When natural disasters disrupt food supply chains, shortages of food on supermarket shelves or higher prices for fresh produce take many by surprise. The interruption to our typical grocery shopping experience, however, is usually short and this apparent capacity to rapidly return to normal functioning encourages Australians – from consumers to political leaders – to assume our food systems are highly resilient. The demonstrated capacity for responsiveness of Australia's food supply chains, however, belies the threats posed by climate change to both agricultural production and food distribution networks.

Since 1910, Australia's climate has been warming: mean surface temperatures over both the land and sea have increased by around one degree, and extreme heat events have increased in duration, frequency and intensity (CSIRO and BoM, 2016, p. 2). Rainfall totals across the south-east of Australia during the April to October growing season have declined since the mid-1990s (CSIRO and BoM, 2016). As greenhouse gas emissions continue to increase worldwide, the global climate system has warmed and this is projected to drive continuing warming in Australia over the coming decades. While rainfall in Australia varies significantly from year to year and decade to decade, climate change projections indicate that the southern half of the continent will receive less rain overall but increasingly in intense events. While there may be fewer tropical cyclones, a higher

Figure 1.1: Elements of Australia's food system



Source: adapted from Erickson (2008) and Spencer and Kneebone (2011)

proportion is predicted to be in extreme categories (CSIRO and BoM, 2016). Globally, "a changing climate leads to changes in the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events" (IPCC, 2012, p. 7).

In its fifth assessment report, the Intergovernmental Panel on Climate Change (IPCC) comprehensively reviewed the evidence for the implications of climate change for food systems and food security (Porter et al., 2014). Food security is defined as "when all people at all times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 2009, p. 8). Food security is determined, therefore, not only by the availability of food but also its accessibility and utilisation. While most of the available research demonstrates the negative impacts of warming temperatures and changing rainfall patterns on crop yields and quality, livestock production and fisheries, the IPCC notes that the non-production elements of food systems are also vulnerable to climate change (Porter et al., 2014). Climate related disasters, such as drought, tropical storms and floods, are noted to be major drivers of food insecurity around the world. The report concludes:

> The overall impact of climate change on food security is considerably more complex and potentially greater than projected impacts on agricultural productivity alone … climate change effects on water, sanitation, and energy availability have major implications for food access and utilization as well as availability. Likewise, changes in the frequency and severity of climate extremes can affect stability of food

> availability and prices, with consequent impacts on access to food (Porter et al., 2014, p. 502).

While the IPCC report has a predominant focus on food security concerns in developing countries, other research highlights that supermarket-based food systems, like Australia's, are also vulnerable to climate change (Vermeulen et al., 2012). These food systems feature strong corporate concentration; large-scale farming; long, often global-scale, supply chains; complex distribution networks; an emphasis on efficiency, minimal inventory, and 'just-in-time' delivery; and maintenance of a 'cool chain' to ensure continuous refrigeration of both fresh and processed foods (Bartos et al., 2012, Ericksen, 2008, Tregear, 2011, Vermeulen et al., 2012). There is a heavy reliance on transport and electricity infrastructures and information and communications technologies to support the supply chains that underpin these systems. This makes supermarket-based food systems "highly susceptible to disruption by weather" (Vermuelen et al., 2012, p. 206) and therefore, highly vulnerable to the increase in the frequency and severity of extreme weather events projected under climate change. Accordingly, it is now well recognised that the implications of climate change for food security are as relevant for developed countries as for those with fragile food systems (Ericksen, 2008, Ingram, 2011).

Over the last decade, Australia has experienced several severe natural disasters, including bushfires, severe storms, tropical cyclones and extensive flooding events that have directly exposed vulnerabilities in the nation's food system. The Queensland floods of 2010-2011, caused serious damage to farming land and infrastructure; destroyed crops and damaged orchards; disrupted roads, electricity and communications systems; delayed transport of food to disaster-affected communities and urban markets; caused spoilage of perishable products; and inundated Brisbane's fresh produce wholesale markets and many food retail outlets (Bartos et al., 2012, DEEDI, 2011). Just two years later, many of these impacts were replayed following another extreme weather event in January 2013 (QFF, 2014). Recent disaster experiences and projected climate changes, therefore, suggest that Australia's food systems are facing escalating climate risks to which they must adapt.

Adaptation to climate change is frequently framed as a technical issue. An alternate perspective, however, is that climate adaptation is an inherently "social and political act" (Pelling, 2011, p. 3). Pelling argues that the urgent need to adapt to climate change is the critical challenge of our time; one that presents an opportunity to re-visit core social values and re-design social and economic structures to address not just climate risks, but broader

issues of environmental sustainability and social justice. Rather than defensive efforts to preserve established systems, Pelling (2011, p. 3) calls for climate adaptation to be pursued in "a progressive spirit" – seeking to find paths that enable economic, cultural and social flourishing that strengthen society and re-shape power arrangements and governance systems. While the role of technological innovation is recognised, there is also a need for "a closer look at social relations and practices… as sites for adaptation" (Pelling, 2011, p.6). A number of authors have noted that disaster events, and how communities respond to them, offer valuable insights into the strengths and weaknesses of social systems and open windows of opportunity for social actors to implement reforms or adaptations or pursue deeper transformations (Davidson, 2010, Ericksen et al., 2010, Pelling, 2011). Ericksen and colleagues (2010), suggest that external shocks, such as climate events, can reveal underlying structural flaws or institutional and policy failures that weaken food systems, while others note that disturbance represents a test of governance arrangements (Cantelli et al., 2011). Yet there is a paucity of social research directed towards understanding the processes of social renewal in the aftermath of crises (Davidson, 2010).

The underlying premise for this thesis is that as climate change drives an increase in the severity and frequency of extreme weather events, Australia's food system – and the agri-food supply chains that underpin it - will require a strong capacity to cope with natural disasters, and potentially, to a more rapid recurrence of damaging events. A failure to adapt to emerging climate risks, such as extreme weather, may threaten Australia's food security.

Because it produces more food than its population consumes, Australia (at a national scale) is considered food secure - creating a significant degree of complacency amongst the food industry, policy makers and the community (AIHW, 2012, Keating, 2013). A number of recent analyses, however, paint a more complex and nuanced picture (AIHW, 2012, Edwards et al., 2011, Farmar-Bowers et al., 2013, PMSEIC, 2010). A number of threats to national-scale food security have been identified, including climate change, land degradation, urban encroachment on agricultural land, mounting pressures on transport infrastructures, and an increasing reliance on imported agricultural inputs and foods[1] (Edwards et al., 2011, Farmar-Bowers et al., 2013, Hughes et al., 2015, Keating, 2013,

[1] Analysis of 2009/2010 trade data, for example, demonstrates that a relatively high proportion of fresh produce consumed in Australia is imported (17% of starchy root vegetables, 19% of vegetables and 34% of fruit) (Growcom, 2011)

PMSEIC, 2010). The risk of transitory food insecurity in Australia is also high: transport infrastructure is vulnerable to extreme rain events, flooding and storm surge; neither the food transport and distribution industry nor supermarkets are well equipped to deal with disasters; there are no food reserves held by governments; and pantry stocks at the household level are low (Keating, 2013). Chronic food insecurity already occurs at individual and household levels and is estimated to affect five to ten per cent of the population (AIHW, 2012). Identified risk factors include social/economic disadvantage, unemployment, remoteness, poor mobility or disability, and older age (AIHW, 2012, Edwards et al., 2011, Keating, 2013). Food security research often focusses on staple foods. Yet an integral aspect of food security is reliable access to affordable fruit and vegetables, as these foods contain vitamins and minerals essential to maintaining health and reducing the risk of disease (FAO, 2011, NHMRC, 2013). The poor nutritional quality of meals has been identified as a significant contributing factor in food insecure households in Australia (AIHW, 2012). Further, the domestic production of fruit and vegetables is particularly vulnerable to the factors that threaten Australia's food security (Growcom, 2011, Lawrence et al., 2013). The availability, accessibility and affordability of fresh produce, therefore, are key considerations for food security research in Australia.

This research brings a social perspective to the question of how escalating climate risks might be managed in Australia's food system. A key consideration here is: who makes decisions regarding climate risks in the food system? In this thesis it is argued that business owners within agri-food supply chains are primary actors who play a central role in determining how climate risks in the food system are addressed. The thesis, therefore, explores what can be learned from food supply chains that have recently been affected by recurrent natural disasters, and situates adaptation to emerging climate risks as a fundamentally social process. The research investigates how actors in food supply chains perceive and govern climate risks and how they have responded to recent severe natural disaster events. It aims to understand how, following these events, actors are enabled or constrained to re-organise their businesses and agri-food supply chains to adapt to the risk of more frequent extreme weather and to explore what resilience might mean in the context of food systems facing climate change. In doing so, the thesis explores the roles of, and interplays between, structures, social relations and actors in the food system and how the agency of supply chain actors is affected by the strongly asymmetrical concentrations of capital, power and wealth with supermarkets, which enables retailers to exert significant influence over food distribution, production and consumption (Lawrence

and Burch, 2007). The study offers insights into whether recent natural disasters in Australia have catalysed adaptation to emerging climate risks and whether supply chain actors are bringing a 'progressive spirit' – as described by Pelling (2011) - to improve food system resilience, sustainability and fairness.

Research focus

To investigate these issues, the study has focused on national-scale fresh produce supply chains that source vegetables from south-east Queensland's Lockyer and Fassifern Valleys – an important production region that has been significantly impacted by a series of severe storms and floods since 2011. The study applies qualitative, interpretive methods to consider five research questions:

1. What have been the impacts, and implications, of recurrent floods in south-east Queensland on fresh produce supply chains?
2. How have supply chain actors made sense of recent flood events, and in what ways do they construct climate risks?
3. In what ways are climate risks governed within fresh produce supply chains?
4. How have actors responded to recent flood events and is adaptation to emerging climate risks occurring? How might risk governance and resilience concepts be applied in fresh produce supply chains to explore these responses?
5. What are the prospects for the resilience of fresh produce supply chains in the face of climate change and what implications are there for food security in Australia?

Pelling (2011, p. 163) argues that to develop an understanding of "adaptive capacity and action requires a lens that can examine organisational behaviour and governance regimes, as well as the feelings, values and actions of individuals". This research, therefore, draws upon three theoretical perspectives that enable an analysis of both structural and agential forces: the social construction of risk, governance (including supply chain and risk governance) and resilience. In particular, the thesis seeks to bring a stronger critical perspective to the concept of resilience – a term frequently imbued with an optimistic and even heroic flavour in popular and political discourse – drawing from diverse theoretical literatures to consider how it might be defined and applied to food supply chains facing escalating climate risks.

Thesis outline

The thesis is structured as follows. In chapter two, a diverse literature is reviewed to bring a critical perspective to food systems facing climate change, and to highlight how food system structures and the agency of, and relations between, social actors each shape opportunities to address escalating climate risks to the system. Food systems are framed as coupled bio-physical and socio-economic systems in which global geo-political power arrangements, and the market power of supermarket chains, strongly influence the ways in which the system operates and how risks are managed by system actors. The supply chains that underpin globalised food systems are discussed and conceptualised as social institutions that play an integral role in responding to climate risks. The governance arrangements in agri-food supply chains are also reviewed, demonstrating that these are largely between private actors - though driven by retailers who are enabled to shift costs, responsibilities and risks back along the chain. The chapter outlines the risks posed by climate change to food systems, and explains how the characteristics of sophisticated supermarket supply chains increase their vulnerability to disruption by extreme weather events that are predicted to occur more frequently in the future. The limited literature regarding natural disaster risks in contemporary, supermarket-based, agri-food supply chains is discussed and the chapter concludes with a review of research regarding the perceptions of, and responses to, climate risks amongst food system actors.

In the third chapter, a conceptual framework for considering resilience to climate risks in fresh produce supply chains is developed, drawing from several theoretical perspectives. The chapter outlines how the ontological and epistemological positions adopted in the thesis are informed by critical realism, and reviews social theories of risk which suggest that risk is both real and socially constructed and also fundamentally linked to the uneven distribution of power in society. Next, the changing nature of risk in contemporary society and shifts towards individualised decision-making regarding risk is explored. The chapter reviews three areas of social theory that inform the study: the social construction of risk, risk governance, and resilience, and discusses how, together, these perspectives provide a framework that accommodates the structural, relational and agential considerations of the research and guides the analysis and interpretation of its empirical data.

Chapter four outlines the methodology and research methods employed in the study. The ways in which a critical realist perspective and Layder's (1998) adaptive theory approach shape the methodology are discussed. A case description of the fresh produce supply chains that are the focus of the study is provided and the qualitative methods used to

gather and analyse the data from this empirical case are described. Finally, the strategies used to manage the ethical considerations of the study are outlined and the limitations of the research methods noted.

The next two chapters present the results of the study. In chapter five, the impacts of recent natural disaster events in south-east Queensland on fresh produce supply chains are presented drawing from supply chain actors' accounts. The findings demonstrate that disaster impacts and vulnerability to risks are unevenly distributed within the supply chain and that rapidly recurring disasters may have weakened the fresh produce supply system. The chapter also explores supply chain actors' perceptions, and social constructions, of recent weather events and climate risks. The results suggest that a shared narrative about Australia's highly variable climate strongly influences a collective construction of climate risk within the supply chain. The chapter explores the factors that appear to shape actors' risk constructs and the diversity of perspectives evident within the supply chain. In chapter six, the governance of climate risks in fresh produce supply chains is analysed to reveal two strongly contrasting approaches. Actors describe how, typically, climate risks have been governed in individualised ways however, in some chains, the emergence of new supply chain intermediaries has facilitated a more collective approach to climate risk governance. The chapter then outlines the responses made by supply chain actors following recent recurrent natural disasters in south-east Queensland. These responses provide insights into emerging adaptations to changing climate risks in supply chains.

The final chapter of the thesis considers the prospects for cultivating resilience to escalating climate risks within fresh produce supply chains and the implications for food security in Australia. Returning to the attributes of agri-food supply chain resilience identified in chapter three, the analysis draws together the study's findings regarding disaster impacts, risk constructs, risk governance and responses by supply chain actors to recent events. It concludes that significant constraints exist to building supply chain resilience to climate risks which may have implications for national food security. The chapter considers how bringing a risk governance perspective may help to engage a wider set of social actors in the process of improving supply chain and food system resilience in the face of climate change. Finally, the chapter explores the theoretical contributions the study has made towards the further development and application of risk construction, risk governance, and resilience concepts in food systems and climate adaptation research.

Chapter Two: Addressing climate risks in agri-food systems and supply chains - the influence of structure, agency and relations

Introduction

This chapter reviews a diverse literature that sets out the context for responses to emerging climate risks amongst actors in agri-food supply chains, considering macro-structural levels through to actor-level perspectives. Queensland's fresh produce supply chains are embedded in and influenced by national and global-scale food systems, so the review begins with an overview of the broad structure and drivers of the wider food system. Critiques from the agri-food literature regarding the features and failings of the system are discussed, which illustrate how existing structures and power arrangements shape the challenges that food system actors face and also their capacity to respond to them. The review then considers supply chains which, in this thesis, are argued to be a key location in which food system actors interact to manage risks. The relational aspects of supply chains are explored by considering how they are conceptualised in business and logistics fields and through research regarding the governance of agri-food chains. Next, the implications of climate change for food systems and food security are discussed, with a particular focus on the impacts of natural disasters on food supply chains. The final section takes an actor-level focus, reviewing the perceptions of climate change and climate risk amongst food system actors, and the evidence for adaptation to emerging climate risks in food industries. The chapter concludes with a summary of the major themes that emerge from the review and highlights critical gaps in the literature that will be addressed in this study.

Understanding agri-food systems and supply chains

The globalised food system

Food systems are described as "all processes and infrastructure involved in satisfying a population's food security", including "the gathering/catching, growing, harvesting …storing, processing, packaging, transporting, marketing, and consuming of food, and disposing of food waste" (Porter et al., 2014 p. 490). Concerns about the consequences for food security of significant and rapid global environmental change have catalysed a dedicated field of food systems research (Ericksen, 2008, Gregory et al., 2005, Ingram et

al., 2010, Ingram, 2011). This research demonstrates that food systems have "mutually dependent and interacting" biophysical and socio-economic components; are complex and operate across multiple scales and levels; and feature many non-linear feedbacks that can generate "uncertain or unpredictable outcomes" (Ericksen, 2008, p. 237). A food systems perspective highlights that potential threats to food security may arise from multiple sources, and demonstrates the need for sociological research to understand the roles of social institutions and social agents in addressing food security. Recognising that outcomes in food systems can be influenced both by structural features and through the actions of actors within the system, Ericksen calls for research focused on "the nature of institutional processes and food system governance" and "identifying the key institutions with which to work to bring about change" (2008, p. 244).

Food regimes analyses offer additional sociological perspectives, highlighting the globalised nature of the food system and the ways in which global power relationships drive its operation and, in turn, structure international circuits of agricultural production, labour and capital (McMichael, 2009). Two distinct historical food regimes have been described (Friedmann and McMichael, 1989), and agri-food scholars are currently debating whether a third, 'corporate-environmental' regime has emerged characterised by free-market principles; supermarket-controlled globally integrated supply chains; supermarket-driven assurance systems for food safety, quality and environmental management; and the emergence of a pervasive influence of the finance sector across the entire food system (Lawrence and Dixon, 2015, McMichael, 2009). Each of the three regimes is argued to have facilitated and reinforced shifts towards industrialised forms of agriculture and mass-scale production of food for trade in international markets while deprioritising and disempowering smaller-scale production systems, localised decision-making and food sovereignty[2] (Lawrence and McMichael, 2012, McMichael, 2009, McMichael, 2013).

These two bodies of literature demonstrate that food systems operate at a global scale and involve far more than agricultural production. Research regarding food systems must, therefore, recognise their multi-scale, multi-level nature (Ericksen, 2008) and the complex interactions between their ecological, physical, economic, institutional and geo-political

[2] Food sovereignty is understood to mean, "democratic control over national food policy and the right of people and communities to control how and what food is produced, and for whom" (Lawrence and McMichael 2012, p. 135).

elements. This literature also points to the important influence of power relations in the food system, which is explored in more detail in the next section.

Features and failings of agri-food systems

In contemporary, urbanised societies, food is predominantly accessed through supermarkets or grocery stores and various food service providers - often multinational take away or fast food chains (Lawrence and Dixon, 2015, Seth and Randall, 2005, Sage, 2012). Accordingly, the food system is geared towards supplying large volumes of both fresh and processed foods to these dominant outlets. Agricultural systems are highly specialised, intensive and industrialised to generate mass production (Lawrence et al., 2013). The role of wholesale markets has diminished due to a shift towards direct sourcing arrangements between retailers and food producers, particularly for fruit and vegetables (Carolan, 2011, Lawrence and Dixon, 2015, Parsons, 1996). Quality and food safety standards are set by retail or food service buyers and formalised in specifications and assurance schemes to which suppliers must comply (Lawrence and Dixon, 2015). Supermarket and food services' supply chains are typically national or global in scale and highly sophisticated, featuring minimal inventory, just-in-time delivery and careful control of temperatures (Ericksen, 2008, Seth and Randall, 2005, Tregear, 2011, Sage, 2012). Transport and logistics services play an essential role moving large volumes of food over increasingly long distances (Ericksen, 2008, Sage, 2013). The international trade of food underpins the system, with significant efforts over many decades to dismantle protectionism and institutionalise principles of free trade (Lawrence et al., 2013). The food system has a high reliance on large-scale farming and high agricultural inputs; sophisticated communication, information, transport and logistics systems and infrastructures; and fuels and electricity - with an increasing energy demand across all aspects of the system (Sage, 2012). The contemporary global food system is becoming increasingly complex and farming is no longer the dominant activity; as a consequence, power and capital have shifted to other actors in the system (Ericksen, 2008, Gregory et al., 2005).

The dominant role played by supermarkets in national and global food systems is well documented (Burch and Lawrence, 2007, Carolan, 2011, Ericksen, 2008, Sage, 2012) and has been described as the 'supermarketisation' of the food system (Lawrence and Dixon, 2015). Supermarket chains now operate in most regions of the globe (Seth and Randall, 2005) and have extended their scope beyond food into household items, liquor, petrol, insurance and banking (Lawrence and Dixon, 2015). While other players, such as agri-

chemical and seed companies, hold significant power in the food system (see Carolan, 2011, Sage, 2012), retailers wield unprecedented influence over all actors, including consumers (Carolan, 2011, Lawrence and Dixon, 2015). Supply chain management is a key strategy supermarkets use to exert their influence and maintain their market dominance (Seth and Randall, 2005). Supermarkets aim to maintain a continuous process of innovation and cost reduction across all aspects of business (particularly through ruthless negotiations with suppliers), and seek to shift "responsibilities (and costs) to other actors" (Lawrence and Dixon, 2015 p. 215, see also Parsons, 1996 and Seth and Randall, 2005). The impacts of this market power, however, can obscure recognition of the intense competition between retailers. For supermarket chains there is no guarantee of success as "the struggle to survive is fierce", "consumers … are unforgiving in their judgement", and food prices in affluent countries are deflating (Seth and Randall, 2005, p. 2).

Three implications of the concentration of supermarket power within food systems most relevant to this research are noted. The first is that the dominance of a small number of supermarket chains globally creates oligopsony power, where there are many sellers but few buyers (and a limited number of retail choices for consumers). Under these conditions, "the seller has little option but to accept the price dictated by the buyer" and buyers are enabled "to set the conditions of almost every aspect of the farming operation whilst leaving the seller liable for most of the risk" (Carolan, 2011 p. 199). Further, "suppliers who experience bad practices cannot openly voice a complaint as the chains almost have the power of commercial life or death" (Seth and Randall, 2005 p. 133)[3]. Producers of highly perishable commodities are particularly vulnerable to buyer power (Carolan, 2011). Second, supermarkets have developed a capacity to not simply sell goods, but to market whole ways of living, positioning themselves as "food authorities" (Lawrence and Dixon, 2015, p. 219) and champions of consumers' interests (Sage, 2012). Finally, and linked to the previous point, supermarkets operate largely beyond the regulatory reach of governments (Burch et al., 2013, Jedličková, 2015, Richards et al., 2012). Despite evidence of predatory practices and unconscionable market conduct by supermarkets towards their suppliers in Australia and the UK (ACCC, 2015b, ACCC, 2015a, ACCC, 2016, Competition Commission, 2008, Harper et al., 2015), the state has taken limited action to address it.

[3] See also a recent report outlining the experiences of Australian growers and wholesalers (ACCC, 2016).

The globalised, supermarketised food system has been robustly critiqued with scholars arguing it does not provide equitable access to food either at global or local scales (McMichael, 2009); drives shifts in food cultures and dietary patterns away from fresh produce in favour of processed foods (Carolan, 2011, Edwards et al., 2011); and generates significant environmental impacts at each and every level of the system (Carolan, 2011, Lawrence et al., 2013, Sage, 2012). Further, due to the growing energy intensity of agricultural production, agri-food supply chains and retailing, the food system is a major contributor to greenhouse gas emissions and, therefore, climate change (Sage, 2013, Vermeulen et al., 2012). Finally, it is argued that complex and interconnected food systems have become increasingly vulnerable to disruption and external shocks and have a diminishing capacity to address their weaknesses (Ericksen et al., 2010, Marsden, 2013, Sage, 2013). Marsden (2013, p. 124) claims the supermarket-based food system globally is "beset by vulnerabilities and lacks the resilience and organizational capacity to overcome the series of landscape pressures that it now faces".

This literature highlights several important considerations relevant to Queensland's fresh produce supply system: the extraordinary power held by supermarkets, the intense competition between supermarket chains, the relentless pressure for lower food prices, and the gradual loss of market share by fresh produce to processed foods. It is particularly noted that perishable foods, such as fresh fruits and vegetables, are especially vulnerable both to buyer power and disruptions to supply. Of greatest concern, perhaps, is the suggestion that while contemporary food systems have become highly vulnerable to disruption, they simultaneously pose significant structural constraints to actors to address the increasing number of challenges they face. This highlights the importance of understanding the ways in which food system actors interact, which will be explored below through the lenses of the supply chain and the governance arrangements that operate within them.

Supply chains as key social institutions in the agri-food system

The review so far has demonstrated the range of environmental, geo-political and socio-economic forces that shape contemporary agri-food systems. In order to improve resilience to climate risks and natural disasters in the agri-food system, researchers argue that it is necessary to identify the key actors and institutions who most directly respond to system signals and who have the potential to make decisions that facilitate system change (Ericksen, 2008, Nelson et al., 2007). A core contention of this thesis is that supply chains are the primary institution in the food system where actors make key decisions regarding

the management of climate risks. The review, therefore, now turns to consider the social aspects of supply chains.

Business and logistics literatures have contributed most to conceptualising supply chains. In their simplest form, supply chains are described as comprising “three entities: a company, a supplier and a customer directly involved in the upstream and downstream flows of products, services, finances and information” (Juttner, 2005 p. 121). Supply chains, however, are increasing recognized not as linear “but complex systems of networks” (Peck, 2006a, p.128) that incorporate living and non-living elements (Pettit et al., 2010, Pettit et al. 2013). While some authors prioritise the economic aspects of supply chains (Christopher, 1992), others emphasise the social and relational aspects, describing “a network of connected and interdependent organisations, mutually and co-operatively working together to control, manage and improve the flow of material and information from suppliers to end users” (Aitken, 1998 in Peck, 2006a, p. 128). Recognising their social, economic and physical dimensions, Peck (2006a, p. 128) defines supply chains as:

> flows of materials, goods and information (including money), which pass within and between organisations, linked by a range of tangible and intangible facilitators, including relationship processes, activities and integrated (information) systems. In practice, they are also linked by physical transport and distribution networks, and national/international communications and transport infrastructures…In their totality, supply chains link organisations, industries and economies.

The literature, therefore, suggests that supply chains are simultaneously physical, spatial, ecological and relational. Their core function is to facilitate flows and value-adding, requiring the efficient operation of transport, storage, information and communication technologies and infrastructures. Yet, the literature also emphasises that supply chains “experience continual turbulence, creating a potential for unpredictable disruptions” (Pettit et al., 2010, p. 1) so another essential function is the effective management of risk (Juttner, 2005, Peck, 2006a, Pettit et al., 2010). In this context, the efficacy of social relations between the participating organisations is perhaps most integral to their success. The literature highlights that mutuality and cooperation between members of supply chains underpins their capacity to manage risk. This requires integration of business processes (Altay and Ramerez, 2010), collaboration, and inter-organisational alignment (Pettit et al., 2010, Seth and Randall, 2005, van der Vorst and Beulens, 1999, Vlajic et al., 2012). Juttner (2005, p. 122) argues that the management of risks in supply chains:

> must have a broader scope than that of a single organization and provide insights regarding how the key processes have to be performed across at least three organisations … it should be recognized that coordination and joint effort rely on dependency, bargaining, negotiation and persuasion across organizational borders and is inhibited by goal incongruence.

This demonstrates that supply chains are, amongst other things, social institutions and that social processes and relationships are integral to enabling the effective management of supply chain risks. This suggests that collaborative efforts between supply chains participants will be necessary to address the risks posed to agri-food systems by natural disasters and climate change. Yet, demands from supermarkets to deliver efficiencies and leanness have been found to significantly constrain business continuity planning and completely inhibit collaborative efforts between supply chain partners (Peck, 2006b). While business and logistics scholars identify the need for cooperative efforts between supply chain partners, little attention is paid to specific mechanisms such as governance arrangements that guide interactions and decision-making. This subject is discussed below.

Governance in agri-food systems and supply chains

The concept of governance recognises that, in many contexts, decision-making and regulatory powers are distributed amongst diverse social actors, including governments, corporate entities and members of civil society[4]. The importance of understanding governance arrangements in agri-food systems and supply chains is widely acknowledged (Ericksen, 2008, Gereffi, 2005, Lawrence and Burch, 2007), particularly for its value in revealing "how corporate power can actively shape the distribution of profits and risk in an industry" (Gereffi and Lee, 2012, p. 25).

Key influences on agri-food system governance are globalisation and neoliberalism (Busch, 2014, Gereffi and Lee, 2012, Lawrence and Burch, 2007). Gereffi and Lee (2012) describe how globalisation has reshaped international production, trade and competition and re-organised industries. In the latter-half of the twentieth century, companies began to reorganise their supply chains to utilise lower cost suppliers in other nations leading to a fundamental shift to global-scale supply chains that were buyer-led rather than producer-led (Gereffi and Lee, 2012). Food supply chains were progressively globalised throughout the 1990s and 2000s, and vegetable supply chains became strongly buyer-led during this

[4] Theoretical understandings of governance are discussed in more detail in the next chapter.

period (Gereffi, 2005). Due to these shifts, supply chain governance became increasingly directed by the lead firm in the chain. As retailers gained greater power in the globalised economy, supply chain governance has become increasingly retailer-driven (Gereffi and Lee 2012, Parsons 1996). These shifts are further reinforced by neoliberal principles that encourage a market logic to prevail throughout the economy and redirect the roles of government towards facilitating the free functioning of the market (Busch, 2014). In neoliberalised global markets, corporate actors increasingly take responsibility for most aspects of governance, which becomes less visible and less democratically accountable, and more focused upon efficiency, competitiveness and the optimisation of profit (Busch, 2014).

In global value chains, three distinct styles of governance have been identified: market, network and hierarchy (Gereffi et al., 2005, Gereffi and Lee, 2012, pp. 25-26). Under market-based arrangements, transactions are relatively simple, there is an arms-length relationship between buyers and suppliers, and price is the central mechanism of governance. Hierarchy describes vertically integrated supply chains controlled by a lead firm. Within networked governance arrangements there are varying degrees of buyer influence regarding what is supplied. Modular networks involve buyers setting specifications for suppliers' products and some exchange of information regarding standards. Relational networks involve a higher degree of buyer-supplier coordination around more complex standards, requiring greater interaction, knowledge sharing, social ties and trust. Within captive networks, a small group of dependent suppliers meet conditions set by, and specific to, a particular buyer. These styles of governance arrangements appear to be broadly applicable to Australia's domestic fresh produce supply chains, with market and modular styles most common and relational styles also establishing within some chains.

Within Australia's agri-food systems, government directly regulates matters such as the use of agricultural and veterinarian chemicals or minimum wage rates for farm and food industry workers. Consistent with global value chains, however, retailer-lead private governance arrangements largely direct how agri-food chains operate, determining matters such as what is supplied, to what specification, from whom, and at what price (Lawrence and Burch 2007). Standards, audits and certification schemes are the key mechanism of retailer-lead governance in agri-food supply chains (Busch, 2014, Gereffi et al., 2005, Lawrence and Burch, 2007, Thompson and Lockie, 2013). Retailers (or food services companies) set produce specifications and standards for food safety and quality,

environmental sustainability, worker welfare or ethical trade arrangements (see for example Coles, 2011, Woolworths Ltd, 2017). Suppliers are required - at their own cost - to keep detailed records and engage third party auditors to certify their compliance with those standards (Gereffi, 2005, Lawrence and Dixon, 2015). These mechanisms of governance in agri-food supply chains have several implications. Firstly, they enable retailers to shift most of the responsibilities and risks associated with the sale of fresh food to their suppliers (Carolan, 2011, Lawrence and Dixon, 2015). Secondly, these arrangements disempower producers, and in particular, disadvantage smaller-scale suppliers (Gereffi, 2005). Thirdly, the audit process reduces the role of trust and communication between suppliers and retailers and replaces these with surveillance and ritualised auditing, emphasising rules at the expense of relations (Busch, 2014, Davey and Richards, 2013). Finally, I contend that an over-reliance on standards and certification as the key governance mechanism in agri-food supply chains may obscure the need to attend to emerging risks that are not currently addressed in existing schemes, such as the escalation of risks driven by climate change.

Climate risks and natural disasters in agri-food systems

The implications of climate change for food systems and food security

An extensive literature has developed to consider the effects of climate change on food production and food systems. Comprehensive reviews by the IPCC (Porter et al., 2014) and Vermuelen et al. (2012) conclude that while climatic shifts may benefit some crops in some regions, overall, climate change poses significant threats to food systems and food security across the world:

> The impacts of global climate change on food systems are expected to be widespread, complex, geographically and temporally variable, and profoundly influenced by pre-existing and emerging social and economic conditions … there is sufficient evidence that climate change will affect not only food yields but also food quality and safety, and the reliability of its delivery (Vermuelen et al., 2012 p. 202).

In several global regions, there is clear evidence that terrestrial food production is negatively affected by climate change (Porter et al., 2014), and crops such as fruits and vegetables - that are water intensive and highly sensitive to heat, weather extremes and water pollution - are most vulnerable (Edwards et al., 2011). While rising temperatures are identified as the key threat to crop yields (Vermuelen et al., 2012), extreme weather events

pose significant threats to all of the three elements of food security (availability, access and utilisation), and climate-related disasters are identified as a key driver of food insecurity – “both in the aftermath of a disaster and in the long run” (Porter et al., 2014, p. 494). Extreme weather events cause crop losses, damage to livelihood assets, soil erosion and degradation, contamination of land and water from polluted floodwaters, and increase the incidence of weeds, pests and diseases (Vermeulen et al., 2012, Webb and Whetton, 2010). Beyond the farm gate, more frequent and severe extreme weather events “can affect volume, quality, safety, and delivery of food in the postproduction stages of the food chain” (Vermuelen et al., 2012 p. 205). Fresh food supply chains have particular characteristics that increase their vulnerability to disruption including: seasonality of supply and demand; limited shelf life and high perishability of products; and the critical need to meet rigid time constraints and also food safety, quality and other customer specifications (van der Vorst and Beulens, 1999, Vlajic et al., 2012). Disruptions to electricity and transport infrastructure impact the cold storage and distribution of fresh food and increase the risk of post-harvest bacterial infections; contemporary food chains following just-in-time delivery modes and holding limited inventory are noted as being most susceptible to disruption (Vermuelen et al., 2012). Extreme weather and climate events are linked to greater instability in food availability, increased food prices, and therefore, reduced food accessibility, particularly for the socially disadvantaged (Edwards et al., 2011, Porter et al., 2014).

The evidence suggests that climate change poses a clear threat to food security due to its impacts on soil and water resources, agricultural yields and quality, and food distribution and accessibility. Extreme weather events are highlighted as a threat to the entire food system and notably, to more sophisticated styles of food supply chains. Indeed, Sage (2013, p. 72) concludes that as they are currently configured, contemporary food systems lack resilience and buffering capacity, making them both highly sensitive to short term episodic shocks and “unlikely to be able to cope with long term stress arising from climate change”. Perhaps of greatest concern, it is noted that in the context of more frequent extreme weather events, “the cumulative effects of disasters at local or sub-national levels can substantially affect livelihood options and resources and the capacity of societies and communities to prepare for and respond to future disasters” (IPCC, 2012, p. 6). The review now turns to consider, in more detail, the implications of natural disasters for food supply chains.

Natural disasters and food supply chains

Natural disasters can be triggered when extreme weather events interact with exposed and vulnerable human and natural systems; they may impact livelihoods, human settlements and infrastructure (IPCC, 2012, O'Brien et al., 2006). Researchers have identified a correlation between the trend of increasing severity and frequency of extreme weather and climate events and more frequent natural disasters (O'Brien et al., 2006). As climate change escalates natural hazards, society's vulnerability to those hazards is increasing due to population growth, urbanisation, globalisation, interconnected economic activities and infrastructures, and a high reliance on electricity (Boin et al., 2010, De Smet et al., 2012). As a result, natural disasters are becoming more complex, generating escalating economic losses and causing more deaths over time (De Smet et al., 2012, O'Brien et al., 2006). Further, the characteristics of contemporary society enable one disaster event to potentially generate multiple cascading effects, with unpredictable consequences (DeSmet, 2012).

Disaster vulnerability is strongly socially determined as it is influenced by risk mitigation and management efforts made by social actors (Gregory et al., 2005, Islam and Lim, 2015, O'Brien et al., 2006). As the nature of disasters changes and intensifies, it is argued that disaster risk management institutions and procedures must adapt to meet evolving challenges (Boin et al., 2010, De Smet et al., 2012, Islam and Lim, 2015, O'Brien et al., 2006). Research efforts to support this have largely focused on international-scale disaster risk reduction and, in Australia, on emergency services and disaster management. This work highlights the need for improved governance arrangements, particularly adaptive forms of governance (Boin et al., 2010, Cantelli et al., 2011, Djalante et al., 2011, Forino et al., 2015, O'Brien et al., 2006) and greater participation, collaboration and sharing of responsibilities between the state and civil society (Council of Australian Governments, 2011, Gissing et al., 2010, Handmer et al., 2013, Howes et al., 2013, Kinnear et al., 2013, Maguire and Hagan, 2007). Other studies highlight the value of a resilience perspective in disaster risk management policy and practice (O'Brien et al., 2006).

Research with a specific focus on natural disasters in supply chains or food systems, however, is limited. Supply chain management and logistics literatures frequently identify natural disaster as a potential source of supply chain disruption (Juttner, 2005, Peck, 2006), yet little research directly investigates disaster impacts on supply chains or opportunities to address these risks. One exception is a study of the impacts of natural disasters on manufacturing supply chains (Altay and Ramerez, 2010). This analysis

showed that natural disasters impact upon the performance of businesses in each segment of the chain, although in different ways, and that decreased cash flow in affected businesses persisted for some time after a disaster event. Upstream supply chain partners were found to be more likely to benefit overall from disasters, whereas downstream partners tended to experience more significant impacts[5]. The authors concluded that, while managers tend to deprioritise disaster preparedness, whole-of-supply-chain efforts to address disaster risk are necessary and that further research should investigate longer term effects of disasters on supply chains, the impacts on connecting sectors such as transport services, and what steps businesses are taking to proactively manage disaster risk (Altay and Rameriz, 2010). A new field of research regarding disaster supply chains offers further useful insights. These supply chains operate in the context where large scale disasters require a rapid response to deliver urgently needed goods to affected communities, and demand effective cooperation between diverse actors from corporate, government and non-government spheres (Boin et al., 2010). By investigating how and why elements of the logistics chain fail, this research has begun to identify enablers of effective disaster supply chains, some of which seem transferrable to conventional fresh food supply chains, such as advanced planning to address known risks and executive support for a culture of preparedness (Boin et al., 2010).

Food systems researchers have suggested adaptive capacity, effective governance arrangements, and resilience as central to addressing the vulnerability of food systems to climate stresses and natural disasters (Ericksen, 2008, Ericksen et al., 2010, Gregory et al., 2005, O'Brien et al., 2006, Park et al., 2012, Sage, 2013). Empirical research has largely focused on the re-establishment of food supply in developing nations immediately following disaster events (Gregory et al., 2005, Horner and Downs, 2010, Pettit and Beresford, 2005). Two recent studies, however, have examined the performance of long and short food supply chains following natural disasters in 2011 in Queensland and New South Wales and the implications for food security and community vulnerability (Singh-Peterson and Lawrence, 2015, Smith and Lawrence, 2014, Smith et al., 2016). Cities with a high reliance on supermarkets were found to face significant food security challenges, whereas in cities where both longer and shorter food supply chains operated, short food chains were less impacted by floods (Smith et al., 2016). The national reach and market power of supermarket supply chains, however, facilitated rapid access to alternate

[5] In the context of a supply chain, downstream refers to the businesses closer to the end users or consumers, while upstream refers to those closer to the raw materials and production segments of the chain.

suppliers and the capacity to use alternate (and longer) transport routes to minimise disruptions to supply of food (Singh-Petersen and Lawrence 2015, Smith et al., 2016). Both studies concluded that long and short supply chains each demonstrated strengths and weaknesses, though neither could be considered resilient in the context of assuring food security following natural disasters.

This literature demonstrates that climate change is linked to an increase in the frequency of natural disasters events, and that natural disasters in the twenty-first century will be more complex and challenging than ever. This demands a shift in the ways society manages disaster risks and an increased emphasis on addressing social factors that contribute to vulnerability. While research with a direct focus on natural disaster risks, impacts and management in food supply chains is limited, the available literature suggests that increased collaboration across diverse social actors, adaptive modes of governance, and efforts to enhance food system resilience should be key areas of focus. It also demonstrates the importance of whole-of-supply-chain efforts to address disaster risks and suggests that action to enhance resilience in both short and long food supply chains may reduce food system vulnerabilities and enhance food security in local communities.

Social responses to natural disasters and climate risks in food systems

The literature reviewed above has described the climate pressures acting on the food system and the structural influences that are likely to affect food system actors' responses to them. Another important influence on responses and decisions, however, are the ways in which risks are perceived and socially constructed (Granderson, 2014, Rosa et al., 2013)[6]. The review, therefore, now considers the ways in which food system actors perceive and respond to climate risks, and their perceptions of the influence of climate change on climate risks. Few studies have developed a holistic understanding of risk perceptions or constructs held by actors within food systems, and no research appears to have focussed on the perceptions of participants in fresh produce supply chains in Australia. As food system actors are located across both rural and urban settings, however, the international literature regarding perceptions of climate change and climate risks amongst urban, rural and farming populations is reviewed. An emerging literature regarding climate change adaptation in Australian agriculture and food industries that

[6] Theoretical perspectives on the social construction of risk are discussed in the next chapter.

takes a whole-of-supply-chain approach is also reviewed for its valuable insights regarding industry members' perspectives regarding climate risks and responses.

Perceptions of climate risks amongst actors in the agri-food system

Studies conducted in many countries have frequently found that a majority of people, from both urban and rural locations, consider that changes in the climate are occurring (Arbuckle et al., 2015, Buys et al., 2012, Prokopy et al., 2015), including 82 per cent of metropolitan, regional and rural Australians (Leviston and Walker, 2012). These surveys, however, also find that around half of those who perceive that the climate is changing attribute the changes to natural variations in climatic patterns (Arbuckle et al., 2015, Buys et al., 2012, Leviston and Walker, 2012). Australian researchers characterised this as "interpretive denial" which "provides a way to admit the existence of climate change yet escape the moral and behaviour imperatives that logically flow from [it]… or excuse not performing behaviours that are difficult to perform" (Leviston and Walker, 2012, p. 284). An alternate interpretation of scepticism amongst rural residents in Australia regarding climate change is that climate variability is considered to be a "normalcy of rural life", which may reduce perceptions of larger scale trends in climate (Buys et al., 2012, p. 239).

Studies of farmers' perceptions of climate change tend to reflect those of the general population. One survey in the USA, found "a few farmers perceive climate change as a risk, others remain unsure about it, and most do not perceive it as a risk at all" (Stuart et al., 2012, p. 323), though another found that 46 per cent of farmers were concerned about the impacts of climate change on their own operations (Arbuckle et al., 2015). In the latter study, more than one third believed that extreme weather would be more common in the future and the authors concluded that recent extreme weather events that affected agriculture in the region "may be helping to move farmers and major agricultural actors toward a problematisation of climate change" (Arbuckle et al., 2015, p. 227). In contrast, Stuart and colleagues (2012) argued that farmers' perceptions of climate risks were varied, complex, and heavily influenced by their world views and repeated exposure to conservative media, and that short term economic goals were often prioritised over recognition of climate risks. A review of studies conducted in the US, Scotland, New Zealand and Australia found that while the majority of farmers felt climate change was occurring, significantly fewer perceived it as a threat to agriculture, leading the authors to concluded that farmers in developed countries may be "underprepared to mitigate risk and or actual yield loss" (Prokopy et al., 2015 p. 501). Research focussed on Australian farmers, however, found that that 68 per cent agreed that climate patterns were changing,

59 per cent believed carbon emissions worsen the effects of natural climate cycles, and 40 per cent were concerned that climate change would affect the viability of their own property (Hogan et al., 2011). Comparative analysis suggests that Australian farmers were more likely to acknowledge anthropogenic causes of climate change than farmers in New Zealand, Scotland and USA (Prokopy et al., 2015). Studies in two rural Australian communities, where the majority of participants considered that the local climate was changing, found that those who linked observed changes to climate change anticipated negative impacts on rural industries, businesses and communities whereas those who perceived the climate as naturally variable did not indicate any sense of urgency for immediate responsive action (Buys et al., 2012). Research in Australian seafood and wine industries found that members perceived that climate risks and impacts were increasing, and that recent experiences of extreme weather events, rising temperatures and heat stress influenced their awareness of climate risks (Fleming et al., 2014, Park et al., 2012).

This literature indicates that there are likely to be highly mixed views amongst members of fresh produce supply chains regarding climate risks and the influence of climate change on those risks. The research suggests that those actors who do not believe human actions are influencing climatic patterns are unlikely to have a sense of urgency about responding to perceived climate changes, are more likely to prioritise short term economic pressures, and may opt for incremental management adaptations. Those who associate perceived changes in climate with anthropogenic causes may be more likely to anticipate increased risks (such as more frequent extreme weather), hold concerns for increased impacts on agricultural productivity or rural business, be motivated to implement management actions to address climate risks, possibly in collaboration with other industry stakeholders.

Responses to emerging climate risks in Australian agri-food supply chains

Understanding efforts made by businesses or industries to adapt to climate change or respond to climate impacts or risks has been identified as an important, but significantly under-developed area of research (Galbreath, 2014, Linnenluecke et al., 2013, Surminski, 2013). Linnenluecke and colleagues (2013) provide a useful review of the extant literature in this field. It has been noted that few studies to date have applied a supply chain perspective in their analyses (Lim-Camacho et al., 2015).

In Australia, responses to climate change have been studied in the sheep/beef, grains, horticulture, and peanut industries (Hogan et al., 2011, Marshall et al., 2014, Milne et al., 2008, WIDCORP, 2009), though the wine and seafood sectors have received the most attention (Fleming et al., 2014, Galbreath, 2011, Galbreath, 2014, Lim-Camacho et al.,

2015, Park et al., 2012). Researchers have demonstrated that businesses and industries most actively pursuing climate adaptations are those that have directly experienced an increase in climate impacts, such as drought or extreme weather events (Fleming et al., 2014, Galbreath, 2011, Lim-Camacho et al., 2015, Marshall et al., 2014, Park et al., 2012). A diverse range of responses to climatic change have been identified including agronomic adjustments such as changes to canopy management, improved water use efficiency or conservation, and adjustment to harvest times. More significant adaptations involve growing alternative crops, diversifying or restructuring farm businesses, increasing off-farm income, or relocating or expanding production or harvest sites (Galbreath, 2011,2014, Lim-Camacho et al., 2015, Marshall, 2014, Park et al., 2012, WIDCORP, 2009). Beyond the production stages, further potential responses identified in the seafood industry included relocation of cold storage facilities, improving transport and logistics services, and pursuing enhanced information sharing, communication and even vertical integration through the supply chain. Research in the wine industry indicates that those who did not believe in anthropogenic causes of climate change and made little distinction between climate and other drivers of industry change generally took a shorter-term, reactive and incremental approach to managing climate pressures. In contrast, those who linked climate change with anthropogenic causes tended to proactively manage climate pressures to achieve present and future benefits and were more likely to interact with other members of their supply chain to develop management responses (Park et al., 2012). Peanut industry members were found to be aware of the need for industry-scale adaptation planning to avoid impacts on the shelling and processing facilities in the downstream supply chain (Marshall, 2014).

Recent research has also drawn attention to the potential roles of government and corporate or supply chain governance in climate adaptation. Galbreath (2011) found that the establishment of an overarching governance mechanism (an environmental leadership team) within a large-scale wine company provided a clear signal of top level support for management responses to climate change and facilitated collective efforts towards adaptation in all levels of the business. In fisheries supply chains, researchers concluded that enhanced linkages and governance structures could support a clearer understanding of impacts and opportunities for adaption throughout the chain and that eco-certification schemes could facilitate greater communication and connections between supply chain partners (Lim-Camacho et al., 2015). This research also found that policy and regulatory frameworks can impede adaptation opportunities in seafood supply chains, highlighting a

need for governments to engage in adaptation planning (Lim-Camacho et al., 2015). Further roles identified for government include maintaining robust public infrastructures that support reliable transport and logistics services, investing in appropriate research and development efforts (Lim-Camacho et al., 2015), providing tax incentives for investment in adaptive actions and making location-specific climate projections available to landholders (Galbreath, 2014).

It appears, then, that a mix of responses to climate risks is occurring in food supply chains, though predominantly within the farm or production segments. As Lim-Camacho and colleagues (2015, p. 604) point out, however, "the interdependences and implicit connectedness of the supply chain makes it essential to take a holistic view of both impacts and potential adaptation actions across the chain". There is an emerging acknowledgement of the need for broader strategies in other segments of the chain such as processing, transport or marketing; for a stronger focus on whole-of-supply-chain research; for enhanced governance arrangements to enable coordinated adaptations; and for governments to engage with food system actors to support responses to emerging climate risks.

Summary

This chapter has established that escalating climate risks driven by climate change have significant implications for food systems and food security and should be a priority focus for management amongst food system actors. The chapter has also demonstrated that food system structures, supply chain relations and governance arrangements, and the actions and decisions of food system actors each has a distinct influence on the prospects for addressing escalating climate risks. Extreme weather events have been highlighted as a key risk, as they are occurring with greater frequency and intensity and can affect food availability, accessibility and utilisation. Further, in the globalised, interconnected and energy-dependent social and economic context of the twenty-first century, extreme weather events have the capacity to cascade into complex and catastrophic natural disasters. Yet, agri-food scholars suggest that the globalised food system - with its lean and highly sophisticated supply arrangements and excessive focus on cost-efficiencies - is increasingly vulnerable to disruption. Supply chains, as social institutions, are argued to be a critical level in the food system in which actors might re-evaluate climate risks such as rapidly recurring extreme weather events, and determine how best to respond to them. There is little evidence, however, that escalating climate risk is recognised by actors in

supermarket supply chains. Further, the literature presented in this review indicates that the capacity of food system actors to respond to emerging climate risks is significantly limited by structural constraints posed by the food system, the uneven distribution of power amongst actors in the system, and governance arrangements that emphasise ritualised adherence to standards rather than interaction to identify and address emerging risks. The available research also suggests that perceptions of climate risks and climate change amongst food systems actors may be highly variable. Within some Australian food industries, however, there is an emerging recognition of shifting climate patterns and an understanding of the need for interactions with supply chain partners to pursue individual and collective management of climate risks.

The literature review has also revealed some significant gaps in knowledge. There has been little or no explicit focus in the business and logistics, disaster risk reduction or agri-food governance fields on the management of natural disaster or climate change risks in food chains. Also, while the business literature identifies the need for cooperative efforts between supply chain partners to manage risk in general, it does not address specific mechanisms for this such as governance arrangements. With its focus on responses to recent natural disasters and the governance of climate risks by actors in fresh produce supply chains, this research helps address these gaps. Another limitation of existing research is its predominant focus on food supply chains in the immediate period following natural disaster events. This thesis extends this field by incorporating consideration of the longer term and cumulative impacts of recurrent natural disasters in the supply chain. Another significant gap is the paucity of knowledge regarding climate risk perceptions or constructs held by food system actors. This study will generate important insights into the social and collective construction of climate change related risks amongst actors in fresh produce supply chains. The next chapter outlines the key philosophical and theoretical concepts that are applied in the research.

Chapter Three: Theoretical perspectives on climate risk and resilience in agri-food systems and supply chains

Introduction

An analysis of responses to natural disasters and emerging climate risks within Queensland's fresh produce supply chains requires the selection of conceptual and analytical tools that accommodate the interface of social and natural processes, as well as interplays between food system structures and supply chain actors. In this chapter, the philosophical positions and theoretical concepts that underpin the research are discussed. The literature reviewed in the previous chapter points to a number of useful theoretical perspectives for the questions posed in this research. The concept of resilience, in particular, is increasingly applied – both politically and academically – to systems or communities facing major stresses to which they must respond. This research offers an opportunity to consider how resilience concepts can be applied to fresh produce supply chains facing increasing climate risks driven by climate change. A diverse theoretical and empirical literature is reviewed to draw together relevant ideas from social-ecological systems, supply chain, disaster and community resilience fields. The chapter also establishes a broader theoretical context for the research by reviewing social theories of risk which explore how risk shapes contemporary society – and how social structures influence risk. The research also draws on theoretical understandings of how risk is socially constructed and how it is governed in contemporary society. Bringing together theoretical perspectives on risk, risk construction, risk governance and resilience provides a powerful set of orienting concepts to support the analysis and interpretation of data gathered in this study, and reflections on these concepts are discussed in the final chapter. The chapter begins, however, with a discussion of the ontological and epistemological perspectives adopted in the thesis.

The critical realist foundations of the research

This research adopts a critical realist perspective. A critical realist ontology holds that a distinct physical and social reality exists independent of our understanding of it, and that this intransitive realm is multi-dimensional, open, stratified and differentiated (Bhaskar, 1998). Within the intransitive realm, entities may have powers that are possessed but not exercised, powers that are exercised but not actualised, powers that are actualised but not

perceived, or powers that are exercised, actualised and (empirically) perceived (Bhaskar, 1998, p. 9). From a critical realist perspective, therefore, the intransitive realm incorporates the domains of the real, the actual and the empirical, and the domain of the real is held to be distinct from and greater than the empirical and actual domains. Accordingly, that which is perceived of reality is not all that is possible, and may obscure what other outcomes or arrangements could potentially occur, given a different set of conditions. For these reasons, critical realism rejects research methods that rely solely on empirical measurement or sense-data (Bhaskar, 1998). Importantly, critical realism recognises an ontological difference between physical and social reality that arises from human agency and the social world incorporating elements of subjective interpretation (Archer, 1998, Edwards et al., 2014)[7]. Society is viewed as being an open system with both extrinsic and intrinsic sources of openness; an essential characteristic of society, therefore, is its capacity to change form (Archer, 1998). A critical realist social ontology, however, holds that in spite of its mutability, intransitive (or enduring) objects exist in the social world, in particular, relations, structural and cultural properties, and human agency (Archer, 1998, Bhaskar, 1998).

Carolan (2005) argues that critical realism offers an ontological framework that enables sociological research to account for the influence of the biophysical realm in the sociocultural realm, while maintaining an analytical distinction between the two. This provides a "conceptual space for the complex relationships that exist between the diverse strata of reality that result in varied affects and consequences" (Carolan, 2005, p. 395). Carolan (2005) notes this is particularly valuable for environmental sociology, in a context where capitalism, globalisation and other socio-cultural processes in late modernity are driving an increase in the intensity of interactions between the natural and social realms.

Another important ontological position of critical realism is that social structures and human agency are separate, and each possesses distinct properties and powers in their own right, as described in Table 3.1 (Archer, 1998, Bhaskar, 1998). This enables social researchers to recognise both the influence of structural constraints on agency, but also the opportunities for agents to reshape structures over time. The social world is understood to be always pre-structured for those living at any particular point in history; yet while we are always acting in a world of structural constraints and possibilities that we did

[7] According to a critical realist ontology, within the physical sciences the Intransitive Domain is considered to be both existentially and causally intransitive. However, in the social sciences, the Intransitive Domain is held to be only existentially intransitive. This is because it is understood that the social sciences are internally related to (or causally interdependent with) their subject matter (Hartwig, 2007).

not create, human agency provides us with the power to either maintain or modify structures in the natural or social world (Archer, 1998, Bhaskar, 1998, Layder, 1998). Critical realist research, therefore, aims to develop knowledge of social phenomena through studying the influence of both structures and agency and the dynamic interplays between them at points in time, and over time. A critical realist perspective also encourages recognition of the influence of relationships (or, webs of social positions) on human agency (Archer, 1998, Porpora, 1998).

Table 3.1 Properties of social structures and human agency

Properties of social structures	Properties of human agency
Anteriority members of society at any given time are born into pre-existing sets of structures Durability structures tend to continue for extended periods of time Capacity to enable or constrain human agency or provide differential access to cultural and material resources	Self-consciousness Reflexivity Intentionality Cognition Emotionality Capacity to form plans, have ambitions, pursue interests, and act collectively

Sources: (Archer, 1998, Carter and New, 2004)

Proponents of critical realism emphasise that the philosophy is primarily ontological and can accommodate a range of epistemologies (Sayer, 2000). Knowledge of all levels of reality is recognised to be socially mediated and therefore contingent, limited and changing (Carolan, 2005). Critical realist research aims to develop knowledge about social reality through a study of mechanisms and relations rather than through observations of patterns of events, and theories are valued for their explanatory, rather than their predictive, power. Interpretation is also recognised as an essential aspect of critical realist social research (Sayer, 2000). From its conceptualisation of a stratified reality and the distinct roles of structures, relations and agency, critical realist research enables the development of rich explanations of social life that recognise the “rooted, emergent, and interconnected qualities” of elements of reality (Carolan, 2005, p. 409). Critical realism, therefore, offers a sound philosophical framework for research aiming to explore how climate risks that are exacerbated by climate change are being addressed by actors within food systems. Of particular value, is its ability to accommodate interplays between the natural and social worlds, between food system structures and the agency of food supply chain members, and the influence of relationships between supply chain members. To build on these

philosophical foundations, the chapter now turns to consider social theories of risk in contemporary society.

Theoretical perspectives on risk in contemporary society

A widely accepted understanding of risk is “a situation or an event where something of human value … is at stake and where the outcome is uncertain” (Rosa 1998, 2003 and 2010 cited in Rosa et al., 2013, p. 21). Building from the critical realist position that an independent reality exists and following Rosa and colleagues (2013), risks (and specifically, climate risks) are understood in this thesis to be ontologically real in that they represent a set of conditions that exist independently of human understandings of them. It is also recognised, however, that human knowledge of risk is socially constructed (Adam and van Loon, 2000, Lockie and Measham, 2012, Rosa et al., 2013). While scientific and technical assessments of risks are made, risk information is filtered through values, beliefs, existing frameworks of meanings, local knowledge, social networks and movements, and the media; therefore cognitive, emotional, cultural and political factors significantly influence the ways in which individuals and groups construct risks (Granderson, 2014, Leviston and Walker, 2012, Lockie and Measham, 2012, Stuart et al., 2012, Zehr, 2015). Accordingly, in this thesis, it is held that risks are both real and constructed - “a type of virtual reality, real virtuality” (Beck, 2000, p. 213) - a position adopted within many risk studies in the social sciences (Lim, 2011, Taylor-Gooby and Zinn, 2006). The “dual reality of risks as the real and constructed presents a paradox” for how society responds to them (Rosa et al., 2013, p. 15).

While risk has always shaped the human experience, some social theorists argue that the nature of risk has changed profoundly and come to play an increasingly important, indeed central, role in organising social life in late modernity (Beck, 1992, Giddens, 2003, Luhmann, 1990, Rosa et al., 2013). The twentieth century saw “a hyper-accelerated change in the number of risks produced, their magnitude, and their global spread” (Rosa et al., 2013, p. 2). Contemporary risks are often systemic, characterised by embeddedness, complexity and scale, and with a capacity to cause ripple or spillover effects that may cascade into complex catastrophes (Rosa et al., 2013, van Asselt and Renn, 2011). Some risks are ambiguous: difficult to define in scope or significance and about which there may be many legitimate viewpoints, values or perspectives that would influence risk assessment and decisions (Rosa et al., 2013, p. 154). Importantly, it is recognised that many risks are manufactured - the product of industrialisation or the modernisation process itself (Beck, 1992, Giddens, 2003). Anthropogenic climate change, described by

Beck as “the embodiment of the mistakes of a whole epoch of industrial capitalism” (2014, p. 169), offers a powerful example of this. It is also argued that the interests and actions of institutions, organisations and the state often contribute to the production of risk; and that the state may act as a “passive bystander or outright facilitator of risky organisational and institutional practices” (Tierney, 1999, p. 234). Social researchers have demonstrated that socio-political forces create and expand physical and social vulnerability to risks, and that disasters - even those triggered by natural hazards - are strongly shaped by social inequality, governance arrangements, or conditions associated with the political-economy (Lim, 2011, Tierney, 2012). A critical perspective in risk research, therefore, can reveal the relationship between risk and power, and demonstrates that risks are not only socially constructed, but also can be socially created and allocated (Tierney, 1999).

Beck (1992) theorised that a heightened awareness of the manufactured risks of modern life may encourage individuals and social institutions to become more reflexive and precautionary in their decision-making and take preventative actions to reduce risks. Yet a diminished faith in industry, scientific experts and government (Beck 1992, Freudenburg, 1993 in Tierney, 2012) leads social actors to be increasingly critical in their use of science to inform risk decisions, instead blending scientific information, personal experience and political knowledge to make their own judgements (Rosa et al., 2013, p. 196). An individualisation of risk assessment and decision making is, therefore, considered to be a key feature of contemporary life (Beck, 1992, Giddens, 2003). This highlights the importance of a theoretical understanding of the social construction of climate risks for this research. Social scientists identify a clear misalignment between techno-scientific understandings of climate change, developed through analysis of global scale data, and the ways that individuals typically construct climate risk drawing from direct senses and experiences (Arbuckle et al., 2015, Galbreath, 2014, Granderson, 2014). Recent research also demonstrates how climate change risks may be collectively constructed within communities (Granderson, 2014). In addition to lived experiences, dominant discourses, shared values and “a set of imaginaries, narratives and representations at work at the community level” were found to shape how communities produce shared meanings and collectively make sense of climate change risks (Granderson, 2014, p. 58).

Social theories of risk, then, highlight several important considerations for this research. Firstly, that contemporary society is confronted with complex and highly embedded risks arising from both natural and manufactured sources - and sometimes the interactions between them. Second, while risks are real, the powerful and complex ways in which they

are socially constructed (both individually and collectively) influence how climate risks may be perceived and managed. Third, risks are deeply situated within social contexts; social and institutional forces strongly shape not only how risks are perceived, but also how they are produced, distributed and regulated. Finally, in a context of diminished trust in government and science, social actors may proactively seek to reduce risks - though their judgements and responses are becoming increasingly individualised. These distinctive challenges demand new approaches to risk in the twenty-first century. Lim (2011, p. 17) argues that “the governance of risk carries such dire societal consequences that it cannot be treated as a tidy and unproblematic exercise of technical analyses and calculated interventions”. A risk governance approach (Rosa et al., 2013, van Asselt and Renn, 2011) has been developed to address the challenges of contemporary risks, and this is discussed below.

Risk Governance

In contrast to classical theories of regulation or economics, which assume that power and control are exercised by a central or dominant actor (such as a government or the market) within a hierarchy, theories of governance are founded on an understanding that power is distributed between many actors in society (Rosa et al., 2013). From sociological and political science perspectives, governance describes a sharing of responsibilities for governing between the state, market institutions, and civil society (Cheshire et al., 2007). Governance studies consider: who is involved in the exercise of power; what roles are played by governments, private agencies, corporate entities, non-political groups and citizens; how power is exercised; what logics of action diverse actors bring; how relationships between those involved are configured; and what dynamic networks emerge from these relationships (Cheshire et al., 2007, Rosa et al., 2013).

A governance approach to risk management practice is increasingly seen as an effective means to generate and implement, with greater confidence and legitimacy, collectively binding policy solutions for complex issues (Klinke and Renn, 2012, Rosa et al., 2013, van Asselt and Renn, 2011). Traditionally, public risk management has been the primary responsibility of governments, drawing heavily on technical expert advice and risk analysis methods that assess probability and likely consequences to determine risk significance (Rosa et al., 2013). Rosa and colleagues (2013, p. 155), however, argue against “technocratic … economic models of risk assessment” that reduce risk problems to a “simple two-dimensional cause and consequence” framing and which heavily rely on

quantitative calculation. Such approaches fail to recognise the dual nature of risks as both real and constructed, cannot adequately grasp the complexity and qualitative dimensions of systemic risks, and do not incorporate a sufficient range of perspectives, particularly of those likely to be affected by risk consequences (Rosa et al, 2013, Tierney, 1999). Risk governance is argued to offer an entirely new approach to addressing contemporary risks, and is described as:

> … the various ways in which many actors, individuals and institutions, public and private, deal with risks surrounded by uncertainty, complexity, and/or ambiguity … includes formal institutions and regimes and informal arrangements. It refers to the totality of actors, rules, conventions, processes, and mechanisms concerned with how relevant risk information is collected, analyzed, and communicated, and how regulatory decisions are taken (van Asselt and Renn, 2011, p. 432).

A theoretically informed, practice-oriented framework is proposed by van Asselt and Renn (2011) to guide the governance of systemic risks, drawing from governance studies and sociological and psychological research regarding risk assessment and decision-making. The authors suggest three key principles to guide the risk governance process: communication and inclusion, integration, and reflection. Communication should aim to build trust and collective learning between risk governance actors and provide “meaningful interactions in which knowledge, experiences, interpretations, concerns, and perspectives are exchanged” (van Asselt and Renn, 2011, p. 439). The inclusion principle indicates more than the involvement of a diversity of actors; it requires that appropriate mechanisms are used to enable all interested and affected parties to contribute to framing the risk and designing management strategies. The integration principle emphasises the importance of gathering relevant information and perspectives from diverse sources to ensure “reversibility, persistence, ubiquity, tolerability, equity, catastrophic potential, controllability” are considered in risk assessment and evaluation (van Asselt and Renn, 2011, p. 442). It also refers to the need for risk assessment, management and communication to be dynamic, interlinked and iterative processes. The reflection principle encourages those involved in risk governance to regularly reflect (individually and collectively) to avoid falling into standardised routines and to re-evaluate the balance between safety and uncertainty.

The application of risk governance to climate risks is an emerging field with research addressing climate change adaptation at city and household scales (Corfee-Morlot et al., 2011, Elrick-Barr et al., 2014) and the management of natural hazards and disaster risks that are escalating due to climate change (Garschagen, 2015, Hegger et al., 2014, Lidskog

and Sjödin, 2016, Walker et al., 2010, Wiebke et al., 2011). In their work on enhancing community resilience to natural hazards, Walker and colleagues (2010) find that Renn's (2008) risk governance framework aligns well with the natural hazards field and offers additional value by emphasising participation by a wider range of stakeholders in risk knowledge sharing, communication and decision-making. They also note, however, that it can under-recognise social vulnerability and the uneven distribution of power between social actors, which may enable more powerful actors to dominate risk decision-making. Further, Walker and colleagues (2010) find that the focus of risk governance on pre-emptive assessment and strategy development make it less useful in the context of disaster response and recovery. They also note that "the relationship between the governance of adaptation to climate change and the governance of risk is still taking shape" (Walker et al., 2010, p. 55).

Erickson and colleagues (2010) note the potential to apply risk governance concepts in food systems research, and this study provides an opportunity to consider their application in the context of climate change-driven risks in fresh produce supply chains. While acknowledging Walker and colleagues' critiques, risk governance offers value to this research for a number of reasons. First, a risk governance approach provides epistemological recognition of the social construction of risk and does not rely solely on technical risk assessment (Rosa et al., 2013). Second, the concept recognises and better addresses the qualitative aspects of contemporary risks, such as the threats climate change poses to food security and other social or cultural values that cannot easily be quantified. Third, risk governance processes encourage recognition of the range of social actors with a stake in climate risk decisions (and risk consequences), and the potential for decision-making power to be broadly distributed amongst actors in the food system. Finally, van Asselt and Renn's (2011) principles provide guidance for how diverse actors might work together effectively on shared risk problems. A limitation of the development of risk governance scholarship and practice to date, however, is a predominant focus on responses to large-scale public risk as a collaborative effort between governments or international institutions, corporate actors and markets, and civil society (generally represented through non-government organisations). While van Asselt and Renn (2011) note that risk governance may operate as an informal process between private actors, empirical research has not addressed wholly private governance contexts. This research offers an opportunity to consider the applicability risk governance in this context.

Resilience

Resilience offers an alternate theoretical perspective on the ways in which systems and actors respond to risk and disturbance. First applied in the fields of mathematics and physics to describe the responses of materials or systems to stress, resilience has been theorised in many disciplines over many decades and applied to a very diverse range of subjects (see useful reviews by Baggio et al., 2015, Norris et al., 2008, Rogers, 2013, Skerratt, 2013). Two major strands of theoretical development have occurred: one in ecology (Holling, 1973) which was subsequently expanded to analyse persistence and transformation in complex social-ecological systems (Anderies et al., 2006, Berkes et al., 2004, Berkes and Folke, 1998, Carpenter and Gundersen, 2001, Folke, 2006, Gunderson and Holling, 2002); the other in psychology and other social sciences to understand human responses to change and hardship at individual, organisational, community and societal levels (Kaplan, 1999, Magis, 2010, Skerratt, 2013). Resilience scholarship can be broadly categorised between systems and individual applications and in both, while resilience can be characterised as an outcome, it is more usefully considered as a process (Norris et al., 2008, Pelling, 2011).

Food security scholars note that resilience concepts offer utility for researchers and policy-makers seeking to address diverse pressures on food systems (Ericksen et al., 2010, Farmar-Bowers, 2013). Tendall and colleagues (2015, p. 19) propose a conceptual framework to operationalise resilience thinking for food systems and food security, in this context defining resilience as:

> [the] capacity over time of a food system and its units at multiple levels, to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances.

The authors suggest that resilience is enhanced in food systems with robustness, redundancy, flexibility and resourcefulness (that is, adaptability) (Tendall et al., 2015). Smith and colleagues (2016) provide the first efforts to theorise resilience in the context of agri-food supply chains affected by natural disasters. They propose scale, diversity, responsiveness and cohesion as key features that support resilience. Their empirical findings confirm the relevance of these features in the immediate period following a flood event, though they suggest further research should address disaster resilience in food supply chains over longer temporal scales (Smith et al., 2016). For this thesis, a wider literature is reviewed to help further operationalise resilience in the context of agri-food supply chains facing escalating climate risks and recurrent natural disasters, and to more

fully conceptualise its social and actor-level dimensions. Social-ecological system resilience theories are taken as a starting point, as these are arguably the most extensively developed and frequently used to provide foundational concepts for other systems-level applications. Next, the application of resilience in the competitive business and market environment of supply chain management is reviewed. Finally, disaster and community resilience literatures are considered for the insights these offer regarding social interactions in the context of significant disruption, damage and distress. From these diverse theoretical strands, attributes most likely to enhance resilience in agri-food supply chains facing escalating climate and disaster risks are identified.

Social-ecological resilience

Resilience in social-ecological systems is conceptualised as both a measure of the amount of disturbance a system can absorb and still remain within the same state, and the degree to which a system is capable of adaptation through self-organisation and social learning (Folke 2006).The process through which complex social-ecological systems cope with, adapt to and shape change in response to disturbance has been described as the adaptive renewal cycle (Folke, 2006). Drawing on observations from ecological studies, researchers suggest that systems cycle through periods of exploitation and exponential change, periods of emerging stability and conservation, periods of collapse or release triggered by a disturbance, then periods of reorganisation and renewal (Folke, 2006, Gunderson and Holling 2002)[8]. The latter two phases are described as the 'back loop'.

This literature provides a set of core resilience ideas: that ecological and social systems are related and coupled, and therefore co-evolve; that social-ecological systems experience periods of growth, stability, collapse and re-organisation; that complex systems feature multiple, non-linear feedback mechanisms, multi-stable states, inherent unpredictability, uncertainty and surprise rather than a single, stable equilibrium; that systems operate across temporal and spatial scales in which adaptive cycles are nested; and that disturbance creates opportunities for innovation, re-organisation and renewal - and is therefore an essential aspect of system development (Folke, 2006). Social processes thought to be essential for social-ecological systems resilience include trust, social networks, social memory, a capacity for self-organising, and adaptive governance (Folke 2006). Empirical studies tend to focus on sustainable ecosystem and natural resource management (Anderies et al., 2006, Anderies et al., 2002, Carpenter and

[8] A historical review by Davidson (2010) found that the stages of the adaptive renewal cycle broadly correspond with patterns of events that occur during periods of major social change.

Gundersen, 2001, Plummer and Armitage, 2007), though research regarding climate adaptation in agriculture and food industries has also adopted social-ecological resilience as a theoretical framework (see, for example Marshall, 2010, Marshall et al., 2014, Park et al., 2012).

Social scientists, though, tend to be cautious in their use of social-ecological resilience theories. The direct translation to social systems of processes observed within ecological systems has been questioned - especially, whether social-ecological resilience can adequately account for the complex operation of structure and agency in society (Adger, 2000, Brown, 2014, Davidson, 2010). Pelling (2011, p. 57) argues that, with its foundations in systems theory, social-ecological resilience applies a "value neutral, realist epistemology" that produces "a rational and structured framework for understanding human action… infused with a sense of technical optimism". He calls for a "a critical engagement with social processes shaping resilience" (Pelling, 2011, p. 43) which, in the context of adaptation to climate change, requires consideration of the contested relationships between nature and society, the political economy, perceptions of risk, and the influence of emotions on decision-making and adaptation choices. The concept of the 'back loop' in the adaptive renewal cycle, however, is identified as an area of significant interest for social research, particularly because processes of social renewal after disturbance have received less attention than the events leading up to social revolution or collapse (Davidson, 2010). So while the social-ecological resilience framework has not been directly adopted for this study, it does provide useful foundations for further conceptual development that applies, modifies and extends resilience theories in the contexts of social and economic systems.

Supply chain resilience

Supply chain resilience is a relatively new field that has grown out of supply chain risk management (Hohenstein et al., 2015, Peck, 2006a, Ponis and Koronis, 2012, Ponomarov and Holcomb, 2009). Its theoretical development has drawn from ecological, social-ecological systems, social and organisational resilience literatures and also disaster and emergency management research (Ponomarov and Holcomb, 2009). Empirical studies have focused on UK or US-based consumer goods manufacturing and retailing companies with global-scale supply chains (Juttner and Maklan, 2011, Pettit et al., 2010, Sheffi and Rice, 2005), while Johnson et al. (2013) considered infrastructure reconstruction supply chains. Food supply chains have received limited attention – though recent floods in

Australia have catalysed investigation of food supply chain resilience following natural disasters (Smith et al., 2016).

The field has been driven by an increasing awareness of the range of vulnerabilities to which supply chains are subject; the volatility and uncertainties arising from contemporary social and economic conditions; and a recognition that the dominant focus on efficiencies and cost minimisation can negatively impact overall chain performance and sustainability (Johnson et al., 2013, Pettit et al., 2010, Ponis and Koronis, 2012). Where supply chain management focuses on reducing vulnerabilities through managing risk, a supply chain resilience approach assumes that not all risks can be prevented and so aims to develop an adaptive capacity to prepare for and respond to unavoidable risk, unexpected disruptions or unforeseeable events (Juttner and Maklan, 2011, Pettit et al., 2010). In theorising supply chain resilience, some authors emphasise maintenance and control of structure and function (Ponomarov and Holcomb, 2009), however, most suggest resilience requires an ability to adapt, re-align resources and implement re-configurations that better suit new conditions and also maintain a capacity within the supply chain to make further adaptations in the future (Juttner and Maklan, 2011, Ponis and Koronis, 2012, Sutcliffe and Vogus, 2003). Importantly, supply chain resilience theories focus on building competitive advantage, an emphasis that sets this application of resilience apart from most others and reflects its market context (Hohenstein et al., 2015, Ponis and Koronis, 2012, Sheffi and Rice, 2005). In this context, then, resilience requires supply chain partners to invest in continuous innovation to enable them to adapt more rapidly than their competitors (Hamel and Valikangas, 2003 cited in Pettit et al., 2010).

Conceptual and empirical research in this field has identified capabilities that contribute to supply chain resilience which can be grouped into technical, economic and social categories. Technical capabilities identified include: redundancy (the availability of spare capacity within the supply chain, including maintaining some inventory); a capacity for responsiveness, flexibility or adaptability (through access to alternate sources of supply or diverse resources and the ability to recover, reorganise, reconfigure or innovate); agility and velocity (the efficiency and pace at which responses or adaptations can be implemented); organisation and cohesion (Johnson et al., 2013, Juttner and Maklan, 2011, Pettit et al., 2010, Ponis and Koronis, 2012, Ponomarov and Holcomb, 2009, Sheffi and Rice, 2005, Smith et al., 2016). Economic capabilities include market position, financial strength and stocks of financial capital (Pettit et al., 2010) and the degree to which the larger companies in the supply chain invest in smaller players (Johnson et al., 2013). Most

supply chain resilience research highlights the critical importance of social capabilities. The most commonly identified is a capacity for collaboration between supply chain partners (Johnson et al., 2013, Juttner and Maklan, 2011, Pettit et al., 2010, Ponis and Koronis, 2012). This requires both a willingness of, and mechanisms for, partners to work together, pursue joint decision-making and planning, and align efforts to address risk or disruption; it also requires a commitment to build social capital, mutually beneficial relationships and avoid opportunistic behaviours (Johnson et al., 2013, Juttner and Maklan, 2011). Collaboration within supply chains also requires a capacity to work effectively in the inter-organisational domain, where issues cannot be resolved by organisations working on their own (Johnson et al., 2013). Information sharing (often termed in this literature as visibility) is well recognised (Christopher, 2005, Juttner and Maklan, 2011, Petit et al., 2010, Ponis and Koronis, 2012), while others identify a capacity to learn, share lessons from disruptions, and implement improvements (Juttner and Maklan, 2011, Ponomarov and Holcomb, 2009). Datta and colleagues (2007) note the importance of proactive planning and structured and integrated efforts to develop the capabilities of all members of the chain. Finally, the role of risk perception and organisational cultures regarding risk management, anticipation or sharing of risk information is noted (Juttner and Maklan, 2011, Pettit et al., 2010, Ponis and Koronis, 2012, Ponomarov and Holcomb, 2009), while Ponomarov and Holcomb (2009) emphasise that the sharing of risk and reward between supply chain members is critical, particularly in situations of high uncertainty.

This literature provides a useful set of concepts and attributes regarding supply chain resilience relevant to the research. Some limitations, though, should be noted. With its focus on global supply chains for construction, electronics, fashion or consumer goods, this body of research may not directly translate to the specific challenges related to the fresh produce industry and its largely domestic supply lines. Also, it does not directly address how the processes and attributes may be affected by high asymmetries of market power, such as those experienced by members of Australia's agri-food supply chains. While natural hazards are identified as a source of supply chain disruption, few studies directly address supply chain resilience in the context of natural disasters or risks related to climate change. Finally, in both the social-ecological systems and supply chain resilience literatures, the social aspects of resilience are identified but, arguably, undertheorised. Accordingly, the chapter now turns to consider the contributions disaster

and community resilience literatures may add to the theoretical foundations of the research.

Disaster and community resilience

Within the natural hazards field, scholars have sought to theorise how communities or places affected by natural disaster might achieve resilience (Cutter et al., 2008, Keogh et al., 2011, Norris et al., 2008, Rogers, 2013). The attributes identified as contributing to disaster resilience are consistent with social-ecological and supply chain resilience, however, the value of this literature (beyond its contextualisation of resilience to disasters) is its deeper exploration of the influence of physical and economic infrastructures and social processes. Also, disaster resilience frames disruptions from disaster events as cyclical risks, in contrast to other conceptualisations which tend to frame disturbances as one-off surprises. Cutter and colleagues' (2008) offer a conceptual model which recognises the influence of, and interplays between, disaster event characteristics (duration, intensity, magnitude, rate of onset and frequency of recurrence); the antecedent conditions of social, natural and built systems and a community's mitigation and preparedness strategies; coping responses and absorptive capacities; and adaptive processes triggered by a natural disaster event. Disaster resilience is defined as: "a process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance" (Norris et al., 2008, p. 130); it enables communities to adapt to new conditions and be well positioned to cope with future events. Norris and colleagues (2008) posit that economic development, social capital, information and communication, and community competence are adaptive capacities that together provide the basis for disaster resilience. Community competence is described as the collective equivalent of human agency and enables a community to "learn about their risks and options and work together flexibly and creatively to solve problems" (Norris, 2008, p. 141). It is argued that community competence enables recovery from a disaster, but also builds a capacity to adjust physical and social environments to address future risks (Brown and Kulig, 1996 in Norris et al., 2008). The disaster resilience literature acknowledges that resources and adaptive capacities "are not static – they evolve, strengthen, weaken, rebound" (Norris et al., 2008, p. 144). It also recognises that environmental risks, vulnerability to hazards, and resources within communities may not be evenly distributed and that disaster resilience requires communities to "develop economic resources, reduce risk and resource inequities, and attend to their areas of greatest social vulnerability" (Norris et al., 2008, p. 143). Norris and colleagues (2008) also note the role of communal

narratives which may help community members develop shared meanings or purpose following a disaster experience and contribute to a sense of community connectedness.

Conceptualisations of community resilience echo the disaster literature in emphasising the importance of communities developing resources, capacities, capitals or stocks and ensuring they have the ability to mobilise and network them when required (Magis, 2010, Skerratt, 2013, Wilson, 2012). This literature, however, challenges the predominant focus on episodic disturbance in social systems triggered by external events, instead conceptualising risk, uncertainty and disturbance as a constant force in the lives of community members which may arise from both external and internal sources (Magis, 2010, Skerratt, 2013). Community resilience literatures also place a stronger emphasis on proactive human agency and collective effort. Magis (2010, p. 406) found that communities that strategically invest various 'capitals'[9] in collective endeavours and shared objectives can create an "upward spiral" of an increasing capacity to respond effectively to change. It is also noted, however, that resilience can be reduced in social contexts where power and privilege is concentrated, as this creates an uneven distribution of agency, can distort feedback signals in systems and may constrain the capacity of social actors to adapt to risks or disruptions (Davidson, 2010).

Conceptualising resilience to natural disasters and climate risks in agri-food supply chains

The literature reviewed above reveals both theoretical and practical considerations that inform an enriched understanding of agri-food supply chain resilience. This thesis aims to advance recent conceptualisations of food system resilience (Tendall et al., 2015) and natural disaster resilience in agri-food supply chains (Smith et al., 2015). Drawing on the literature reviewed in this and the previous chapter, this thesis makes three important contributions to conceptualising food supply chain resilience to emerging climate risks. First, it emphasises that as climate change drives an increasing intensity and frequency of extreme weather events, the risk of natural disasters disrupting food supply chains should be understood to be cyclical rather than episodic. In this context, resilience (and food security, more broadly) requires not only a capacity to recover from a singular natural disaster event but an ability to manage recurring events, and even rapidly recurring events. Second, the recognition that it is actors at the supply chain level who play the primary role in managing climate risks in food systems highlights that a conceptual

[9] Magis (2010) identifies that community capitals are comprised of natural, human, financial, built, social, political and cultural capitals.

framework for resilience must incorporate an explicit focus on social factors at institutional, organisational and individual levels that may underpin pre-emptive and collective risk management actions. Finally, because agri-food supply chains are strongly driven by supermarkets, conceptualisations of resilience in food systems must recognize the influence of highly-uneven market power on the distribution of agency in the supply chain.

While understandings of resilience as stability and functional persistence or as adaptability remain the subject of debate (Brown, 2014, Matyas and Pelling, 2014), in this thesis, resilience is considered to be a process that enables adaptation. In the context of the three key considerations outlined above, the attributes and actions that I contend are most relevant in enabling a capacity for resilience to climate risks and natural disasters within agri-food supply chains are presented in Table 3.2. The review of resilience literatures suggests that agri-food supply chains with these attributes would have an enhanced capacity to cope with shocks and stresses and to thrive in the face of disruptions; an ability to use supply chain disruptions to implement innovation and renewal that builds competitive advantage; and a capacity to become increasingly well-adapted to changing environments and emerging climate risks.

Towards a theoretical framework for climate risk and resilience in agri-food supply chains

The theoretical literature discussed in this chapter provides a framework of orienting concepts that inform the research and guide the interpretation of its empirical findings. Social theorists have demonstrated that risk has a powerful, organising influence in contemporary society and that the processes of modernisation and globalisation directly generate risks. While recognition of the manufactured nature of many contemporary risks may motivate reflexive responses in social actors and institutions, it also diminishes trust in science and government – driving an individualisation of risk assessment and decision-making. This literature also informs a critical understanding of climate risks in food systems as both ontologically real and socially constructed (individually and collectively). Social-ecological resilience theories suggest that coupled ecological and social systems typically move through cycles of growth, conservation, collapse and renewal, and that disturbance can be conceptualised as integral to the development of the system. In the context this research, then, climate events that disrupt food supply chains may catalyse opportunities for reorganisation or system renewal. The study's critical realist perspective

Table 3.2 Proposed attributes of resilience to natural disasters and climate risks in agri-food supply chains

Attributes	Actions
Shared intent amongst supply chain members	Anticipate cyclical climate risks and take a proactive, structured and integrated approach to their management (Cutter et al., 2008, Magis, 2010, Skerratt, 2013) Make collective efforts to shape future outcomes rather than react to events as they unfold (Skerratt, 2013)
Planning	Define shared objectives (Johnson et al., 2013, Magis, 2010) Develop a planned trajectory (Skerratt, 2013)
Collaboration	Build trust-based relationships and social capital (Johnson et al., 2013) Facilitate open communication (Juttner and Maklan, 2011) Facilitate information sharing, particularly risk information (Juttner and Maklan, 2011, Ponomarov and Holcomb, 2009) Capacity to work in the inter-organisational domain (Johnson et al., 2013, Juttner, 2005) Shared decision-making (Ponis and Koronis, 2012)
Learning	Support cultures of learning and collective reflection on experiences to identify lessons (Juttner and Maklan, 2011, Ponomarov and Holcomb, 2009) Cultivate information sources and develop risk knowledge (Juttner and Maklan, 2011, Norris et al. 2008) Regularly refine (climate) risk management procedures / strategies informed by new information and lessons learned from experiences (Ponomarov and Holcomb, 2009)
Adaptability	Develop capacity for rapid responsiveness, flexibility, improvisation (Juttner and Maklan, 2011, Pettit et al., 2010, Ponis and Koronis, 2012) Strategically invest in resources, capabilities and innovation to enhance ability to re-organise or re-configure (Pettit et al, 2010)
Connectivity	Implement mechanisms that enable networking of resources between supply chain partners, when required (Johnson et al., 2013, Norris et al., 2008)
Equitable distribution of risk and reward	Implement mechanisms to share risk between supply chain members (Ponomarov and Holcomb, 2009) Lead firms invest in smaller suppliers (Johnson et al., 2013) Distribute returns/profits between supply chain members to optimise financial capacity of all (Norris et al., 2008, Adger, 2000, Ponomarov and Holcomb, 2009)
Reserves	Maintain some redundancies within supply chain (Ponis and Koronis, 2012) Build up (financial) reserves and capitals / avoid erosion of capitals (Magis, 2010, Pettit et al., 2010) Protect core assets (Pettit et al., 2010)

Source: author's own synthesis, drawing from theoretical and empirical resilience literatures reviewed in this chapter.

enables an explicit recognition of the interrelationships between biophysical and sociocultural elements of reality, as well as the interplays between the distinct causal powers of food system structures, relations and the agency of food system actors which can each enable or constrain responses to recurrent natural disasters and emerging climate risks within fresh produce supply chains. A governance perspective suggests that decision-making power regarding climate risks in food systems is not centralised but distributed amongst members of the supply chain. Critical sociologies of disaster, though, highlight that an uneven distribution of power within the food system may strongly influence the distribution of disaster and other climate-related risks.

Two operational theories of how risks may be addressed collectively by actors in coupled social-ecological systems have been reviewed. Risk governance and resilience concepts each offer value to this study of climate risk management, recovery from natural disasters, and climate change adaptation in fresh produce supply chains. Theories of risk governance offer normative guidance for processes that supply chain actors might follow to assess and share information about climate risks and enact strategies to reduce or manage them, and highlight the need for communication, inclusion, integration and reflection. Further attributes and actions that would support the development of effective responses to natural disasters and climate risks emerge from resilience literatures. These suggest that supply chain resilience to climate risks may be enhanced by members developing a shared intent and efforts towards joint planning, collaboration, learning, adaptability, connectivity, equitable distribution of risks and rewards, and seeking to maintain sufficient reserves. Both concepts highlight the importance of anticipation of risk; the essential role of agency and collective effort to proactively manage risk; the requirement for open communication, collaboration and trust-based interactions between actors; and the cultivation of diverse information sources and collective learning and about risks and potential consequences. With its stronger sociological foundations, risk governance directly accommodates the potential ambiguity or diversity of legitimate viewpoints regarding risks, and therefore the deep complexities associated with how social actors assess and manage them. Following from their systems foundations, the distinct value of resilience theories lie in a clearer conceptualisation of the spatial, temporal and cyclical dimensions of risk; a stronger emphasis on responses to and recovery from actualised risks; and recognition of the need for social actors to enhance their adaptability to changing conditions. Having developed the theoretical foundations for the study, the next chapter describes the research methodologies and methods that have been followed.

Chapter Four: Research methodology and methods

Introduction

This chapter provides an overview of the methodology and qualitative methods that have been employed in this study. Following a brief outline of the research design process, the research methodology is discussed to outline the ways in which a critical realist perspective and an adaptive theory process shaped the research. A description of the vegetable supply chains that are the empirical focus of the study is provided. This includes an overview of the farming regions in south-east Queensland from where the produce is sourced as well as the extreme weather events that affected the region and wider supply chain in recent years. The methods followed in gathering and analysing the data and managing the ethical considerations of the research are outlined. Lastly, the limitations of the methods are noted.

Research design

A detailed research design was prepared to guide the conduct of this study, following the procedure proposed by Blaikie (2010). This facilitated careful consideration of the essential aspects of rigorous social research and supported the selection of a philosophical stance, identification of appropriate research methods, and valuable reflections on the motivations, assumptions and perspectives I bring to the study. At important points in the research process, such as the commencement of field work or data analysis, the research design was reviewed and revised, reflecting the iterative and reflexive nature of the social research process (Blaikie, 2010, Mason, 2002).

Qualitative social research emphasises an explicit recognition that researchers are biographically and socially situated, and that the researcher's class, gender, race, culture, and existing sets of ideas sit "behind and within" each phase of the research process (Denzin and Lincoln, 2008 p. 28). One aspect of my own situated perspective is my professional role with Queensland's fruit and vegetable growers' industry association, Growcom, where I have worked for over fifteen years in policy, advocacy and project management roles. Over the course of this research, in my Growcom role I have delivered workshops for horticultural growers regarding natural disaster preparedness, risk management, recovery and resilience. This has enabled an interplay throughout the research process between a more normative, practice-oriented perspective and a

theoretically-informed, analytical and critical perspective, which has benefited and informed both the research and my professional practice.

A methodology informed by critical realism and adaptive theory

As outlined in the previous chapter, this study takes a critical realist perspective. While critical realism is adopted more as an ontological framework than an analytical lens, it does shape the study's epistemological and methodological considerations in several important ways. Firstly, while critical realism holds that there is an external physical and social reality that is independent of our knowledge of it, the social world is understood to be socially constructed through our subjective interpretations of it (Edwards et al., 2014, Sayer, 2000). Critical realist research, then, seeks to engage in the development of both causal explanations and interpretive understandings of the social world (Bhaskar, 1998, Sayer, 2000). While the scope of the thesis constrains the opportunity to develop detailed causal explanations, it does seek to bring interpretive and critical analysis to the research process. An interpretivist methodology is employed to develop an understanding of the research questions through gathering perspectives from the research participants and inductively and abductively drawing meanings and interpretations from these data (Blaikie, 2010, Ormston et al., 2014). It is recognised that my observations are not objective or 'value-neutral' and that my interpretations are conceptually mediated and draw on social theories.

A second way in which critical realism shapes the methodology is its assertion that structures, agency and social relations are independent, have distinct properties and, therefore, possess causal powers in their own right (Bhaskar, 1998). This perspective encourages analysis of the separate influences of agency, relations and structures and the interplays between them (Layder, 1998, Sayer, 2000). For this research, this suggests the importance of investigating the actions supply chain members are taking in response to climate risk (agency); considering how food system structures and supply chain relations (including governance arrangements) motivate, enable or constrain the agency of supply chain members; and, analysing the ways in which supply chain members' actions can reshape supply chain relations and food system structures.

A third influence on the methodology is critical realism's emphasis on interdisciplinary research, which is considered to be necessary to develop understandings and explanations of a multi-dimensional, stratified, and open reality (Bhaskar, 1998, Sayer,

2000). In reviewing empirical and theoretical literatures, this study has drawn from many disciplines, including sociology, geography, business studies and climate science and integrated knowledge from diverse fields including agri-food studies, governance, supply chain management, and climate change adaptation. These diverse perspectives have helped to demonstrate both the multi-faceted nature of fresh produce supply chains and the various social, historical, cultural, economic and physical factors that shape supply chain actors responses to natural disasters and emerging climate risks.

A further important aspect of the study's methodology is the adoption of an adaptive theory approach which combines "an emphasis on prior theoretical ideas and models which feed into and guide research while at the same time attending to the generation of theory from ongoing analysis of data" (Layder, 1998, p. 19). The prior theoretical ideas, or orienting concepts, that have been applied to the analysis of this study's findings are risk governance, resilience and the social construction of risk. Their purpose was "to produce an additive or incremental effect on one's conceptual and theoretical thinking" and "provide a terms of reference for the further elaboration of theoretical ideas" (Layder, 1998, p. 129). Following this approach, the orienting concepts offered a provisional means of organising the data, and where the empirical evidence supported a concept, it provided "a centre point for conceptual extension and theoretical elaboration" (Layder, 1998, p. 110).

Finally, the study of how social actors and institutions within food systems address escalating climate risks driven by climate change required the selection of an empirical case which offered a manageable scale for the research. Fresh vegetable supply chains, sourced from produce grown in south-east Queensland's Lockyer and Fassifern Valleys, were selected to provide the empirical focus for this study. This case provided a compelling example of a supply chain that had recently been impacted by extreme weather events of the intensity and rate of recurrence that are projected to affect the food system under climate change. Further, these supply chains are predominantly directed towards serving the major supermarkets, and therefore reflected the characteristics and concerns described in the agri-food literature. This provided an opportunity to investigate the influence of governance and power arrangements highlighted in the literature on supply chain members' capacity to recover from natural disasters and respond to future climate risks. A further consideration was that my role with Growcom facilitated an 'insiders' access to these supply chains.

Case description

Queensland is recognised as the largest producer of vegetables in Australia (DAFF, 2014, James, 2013) and the Lockyer and Fassifern Valleys are a nationally significant production region (Table 4.1). A map of the study region is provided at Figure 4.1. These valleys are known for their highly fertile alluvial soils and produce a diverse range of vegetables, including lettuce, potatoes, cauliflower, broccoli, carrots, onions, sweet corn and beans. Agriculture is the most important source of employment in the Lockyer Valley, with 25 per cent of its workforce employed in the industry (Stafford Group, 2013).

Table 4.1 State and national significance of vegetables produced in south-east Queensland

	South-east Queensland (hectares of production) 2011/12	Queensland (hectares of production) 2011/12	Australia (hectares of production) 2010/11	SEQ % of Queensland area production	SEQ % of Australian area of production
Carrots	880	955	4,636	92%	25%
Broccoli	1,152	1,591	7,090	72%	16%
Onions	559	992	6,139	56%	9%
Lettuce	754	2003	9,071	37%	8%

Source: ABS Catalogue 7121.0 - Agricultural Commodities, Australia, 2010-11 and 2011-12

Vegetables grown in the district are destined for a diverse array of local, regional, state, national and international markets, though a very high proportion of produce is sold through Australian supermarkets (Stafford Group, 2013). Traditionally, vegetable growers strongly relied on one or a number of agents in wholesale markets in capital cities to facilitate the sale of their produce. Pathways to markets, however, have become more diverse and growers increasingly harness multiple supply chains to sell their produce to a range of customers (Figure 4.2) – though a very strong competitive culture remains amongst growers.

One notable shift has been the establishment of direct supply relationships between growers and major supermarkets (Parsons, 1996). In these cases, produce is delivered direct from a grower's packing facility to a supermarket distribution centre. Another shift is the emergence of companies, known as packer-marketers, who act as specialist supply chain intermediaries. These companies secure large-scale customers, particularly supermarkets, and coordinate a network of grower suppliers to service them. In some cases, packer-marketer companies achieve a highly sophisticated degree of supply chain

Figure 4.1 Map of Queensland with the south-east Queensland study region and Lockyer and Fassifern Valleys inset

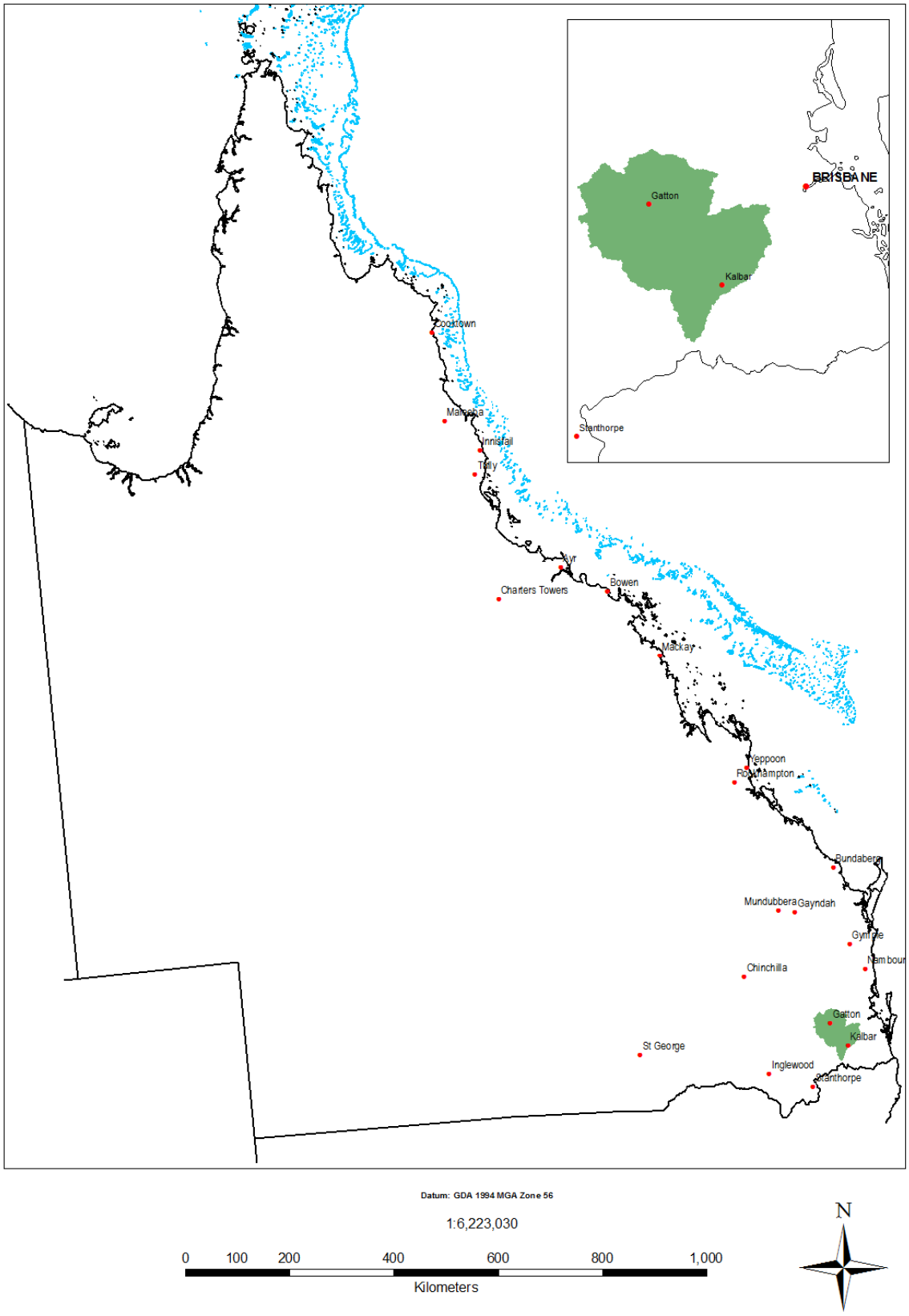
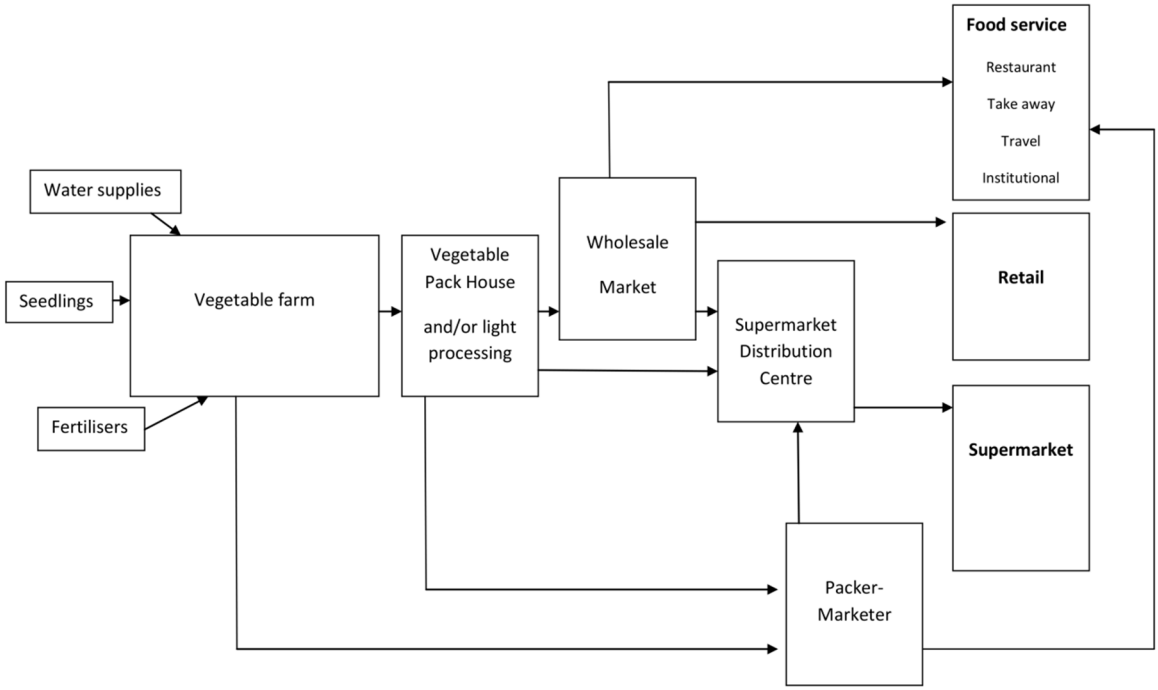


Figure 4.2 Elements and pathways within contemporary vegetable supply chains



Source: author

integration, and work to meet identified market demands or trends with specialist produce which may involve collaboration with commercial seed producers to create hybrid products; development of specialised production systems; or innovative processing or packaging methods. It should also be noted that some actors play multiple roles within the supply chain: some growers pack their own produce and offer packing services to other growers; some growers operate large-scale packing facilities and pack and market vegetables for a network of growers; some pack houses operate a wholesaling business; some wholesalers also operate farms – and vice versa; and some packer-marketer businesses own or co-own extensive farming operations. While a diminishing volume of vegetables is sold through wholesale markets, wholesalers are still active within vegetable supply chains with an increasing focus on smaller retailers, the food services sector, and export markets. Fresh vegetables are almost exclusively transported via refrigerated trucks and accordingly, vegetable supply chains are highly dependent on rural and urban road infrastructure and the national highway network. Many freight companies offer cold storage facilities and logistics services including coordinating the assemblage and delivery of consignments and orders. Vegetable supply chains, therefore, are often not simple or linear – with implications for their governance arrangements, which are discussed in the following chapters.

Over recent years, vegetable supply chains in Queensland have been disrupted by a series of extreme weather events and natural disasters. The most significant was the Queensland floods of 2011. Following an exceptionally wet year in 2010 (BoM, 2012), the summer of 2010/2011 brought a series of six major rain events to Australia's eastern states that lead to "widespread flooding on many rivers and culminating in severe flooding … in Brisbane" (BoM, 2011, p. 2). Continuing rain subsequently caused significant flooding in New South Wales, Victoria and Tasmania. The flooding, "in terms of extent, impact and severity, was amongst the most significant in Australia's recorded history" (BoM, 2011, p. 2). Damaging floods affected the Fassifern Valley, however, the Lockyer Valley experienced catastrophic impacts: nineteen people died, 2 300 houses were inundated, farmland and infrastructure was severely damaged, 40 of 48 council-owned bridges were damaged, and 1100km of 1400km of council-owned roads were damaged (Queensland Floods Commision of Inquiry, 2012, Rogencamp and Barton, 2012). In the wider region, the central fruit and vegetable wholesaling facility (the Brisbane Markets) was inundated and closed for five days, the Coles distribution centre was flooded, many regional roads were closed, and more than thirty Coles and Woolworths stores across the state were either inundated or closed due to a lack of stock (Bartos et al., 2012, Queensland Reconstruction Authority, 2011, Sydney Morning Herald, 2011, Wesfarmers, 2011).

Just two years later, another extreme rainfall event affected large areas of Queensland as Tropical Cyclone Oswald crossed the coast in the Gulf of Carpentaria, became a slow-moving tropical low and followed a path south bringing heavy rain and destructive winds (BoM, 2013). The Lockyer and Fassifern Valleys were again severely flooded (SEQ Catchments, 2013). This time, the Fassifern was the worst affected: "...parts of the Scenic Rim area on the southwestern edge of the Brisbane River catchment … had sites with 24-hour totals in excess of 700 millimetres" (BoM, 2013, p. 2). Across the region, farmland and infrastructure, local roads and bridges, and power and telecommunications infrastructures were again severely damaged (QFF, 2014). Economic losses to the Lockyer Valley vegetable industry were estimated to be $35 million (Queensland Farmers' Federation, 2014). Extensive flooding did not extend to the city or the wholesale markets. Electricity supplies were affected in Brisbane, however, and severe weather and localised flooding across Queensland and New South Wales cut roads and highways, causing disruptions to fresh produce supply chains (QFF, 2014, Queensland Government, 2013). Another, more localised, extreme rain event occurred in March 2014 which affected farms

in the Fassifern Valley and southern Darling Downs and caused further significant crop losses.[10]

Qualitative data gathering and management

The perspectives of actors involved in vegetable supply chains in south-east Queensland regarding recent natural disasters and climate risks provided the primary qualitative data for this study. Data was gathered from the research participants through semi-structured interviews. Following procedures suggested by Mason (2002), the interview structure was developed to embed the research questions and intellectual puzzle within the interview process and to ensure that the interviews generated meaningful knowledge. A strategic sampling method was employed to select a "relevant range" of businesses from each of the key segments of the supply chain (Mason, 2002, p. 124). Using a purposive approach (Blaikie, 2010, Ritchie et al., 2014) and drawing on my industry networks, interviews were sought with the primary decision-makers in the selected business who could provide insights into the research questions. Snowball sampling was also used when research participants recommended others who had valuable perspectives to offer. The majority of interviews were conducted face-to-face at the participant's own place of work; two interviews were conducted over the telephone. These settings are described as semi-natural: where individuals report on their own and other's activities, attitudes, motives, social processes, and institutionalised practices that occur in their natural settings (that is, their farm or business environment and their interactions with other businesses in the supply chain) (Blaikie, 2010). Interviews were conducted between July 2014 and March 2015, and ranged from forty minutes to two hours in length (though typically around an hour).

In total, eighteen interviews were conducted for the study: sixteen with representatives of businesses from across the supply chain; two with industry disaster recovery support personnel who could provide valuable broader insights gained from their work with a large number of businesses following recent disasters. Two representatives of the business participated in some interviews: in the case of farming/packing businesses this was husband-and-wife business partners, while for the two freight companies this was a business owner and a senior manager. Interviews were sought with the three major

[10] Local rainfall records accessible at http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_startYear=&p_c=&p_stn_num=040867

national supermarket chains (Woolworths, Coles, ALDI) and also Metcash/SuperIGA, but an interview was secured with only one. Insights into the practices and responses of other supermarkets were gained, however, from interviewees who directly interact with them. To protect the identities of the research participants, pseudonyms have been used in presenting the results of the study. Table 4.2 provides a summary of the participants in the study, their supply chain or industry role, and the pseudonyms used in the thesis.

Where research participants provided consent, a digital recording was made of the interviews. A professional transcriber was engaged to generate verbatim transcripts from the audio files; these transcripts were reviewed to check for accuracy. A small number of poorer quality recordings were transcribed by the researcher. Three interviews were not recorded, so brief notes were taken during the interview then further details were added to the notes shortly after the interviews were completed. These notes were typed up by the researcher. Following all interviews, field notes and reflections were made.

Qualitative analysis

The interview transcripts provided the primary data set for the study. To begin the analysis, each transcript was read several times to build a strong familiarity with the data. The transcripts were read "literally" (Mason, 2002, p.148) with attention paid to the direct content, in particular, actors' descriptions, characterisations, opinions and explanations. The transcripts were also read "interpretively…reading through or beyond the data" (Mason, 2002, p. 149) with the aim of inferring from interviewees' accounts deeper or wider meanings, constructs, or motivations, or to identify implicit norms, discourses or rules that may influence supply chain actors' actions or decisions.

Following Mason (2002), an indexing system was applied to the dataset. Using the qualitative data analysis software, NVivo 10, all transcripts were coded. Some codes were developed from the data, while others were informed by theoretical concepts of resilience and risk governance. The coding process enabled a systematic and routine scrutiny across the dataset and helped to move the analysis beyond an "impressionistic view" of the data (Mason, 2002, p. 152). The coded data were used to begin to identify themes and interpretive analytical categories. Working with the de-contextualised segments of text, however, proved problematic for tracing the links between interviewees' responses to the main areas of inquiry of the study. Accordingly, a data summary framework was developed to supplement the coded data (Spencer et al., 2014). This step enabled literal and inferred

Table 4.2 Research participants

Supply chain or industry role	Number of businesses interviewed	Pseudonym used in thesis
Grower • Both supplied more than one pack house in the study region.	2	David John and Rachel
Grower/Packer • There are varying business models: some grow and pack only their own produce; others grow and pack as a corporate family farm business with supply arrangements in place with large networks of other growers.	5	Leanne and Craig Liz and Peter Sally and Michael Stuart Kate
Pack house • The interviewee was the manager of the pack house and also a grower-supplier to the pack house.	1	Mark
Freight and logistics • Both companies specialise in refrigerated truck transport of fresh produce.	2	Tony (owner) and Rob (CEO) Graham (owner) and Scott (Senior Manager)
Intermediaries • Wholesaler 1 • Wholesaler 2 • Wholesaler 3 (organic) • Packer-marketer	4	Alex Tim Chris George
Retailers • Supermarket • Farmers Market[11]	2	Simon Martin
Industry Disaster Support Personnel • Horticulture Industry Recovery Officer (IRO) • Financial counsellor	2	Anne Neil

insights to be drawn out from each interview transcript into a standardised pro-forma that captured the main areas of inquiry along with essential contextual information regarding the business and supply chain arrangements it operated within. Moving between the coded data and the summary matrices facilitated a more nuanced and contextualised means of identifying themes and patterns in the data that supported both an inductive process as well as consideration of the influences of food system structures, supply chain relations, risk constructs, and other factors on the views, actions and responses of research participants. Through the thematic analysis process, detailed descriptions

[11] Due to a shift in focus of the research, the data gathered from the farmers' market representative was not included in the analysis presented in this thesis.

regarding the research questions were developed, while connections between the empirical data and core theoretical ideas underpinning the research - particularly the social construction of risk, supply chain governance, risk governance and resilience - were examined. These are presented in the following two chapters.

Management of ethical considerations

Prior to commencing the interviews, an application for ethical approval was prepared and submitted to the School of Social Science Ethical Review Panel (SSERP). Clearance was obtained in June 2014[12]. The researcher also completed a research integrity module for social and behavioural science researchers through the University of Queensland Graduate School. Together these guided the development of strategies and procedures to manage the ethical issues that arose from the research.

Informed consent was obtained by providing prospective research participants with a written summary of the project (Information Sheet) along with a Consent form that stated that participation in the research was voluntary, that information they provided would remain confidential, and that participants were free to withdraw from the research if they wished to at any time. Interviews were only conducted with participants who signed this consent form, and copies of these were scanned and stored on a password protected computer.

To protect the confidentiality and privacy of participants, a unique identification code was applied to each audio recording or set of interview notes. Interview transcripts and notes were stored electronically on a password protected computer, filed under the interviewee's identification code. Under the agreement with the transcription service, Pacific Transcriptions, adherence to ethical and confidentiality requirements was guaranteed. Any identifying information related to the interviewee or other companies or persons was removed from the transcripts. In a separate file, the identification code was linked to the interviewee's pseudonym. Only the pseudonyms of the participants have been used in the presentation of the research results.

The third key issue was managing any perceived conflicts of interest between my role as a researcher and my roles with Growcom, which involve policy analysis and advocacy work that represents the interests of fruit and vegetable growers in Queensland. To address this

[12] The ethical clearance number for this research project is RHD3/2014.

risk, I provided full disclosure to research participants of my dual roles as researcher and industry policy practitioner. At the stage of initial contact with participants and again at the beginning of an interview, I outlined my personal, professional and academic commitment to facilitating cooperative and respectful approaches to improved supply chain collaboration between supply chain members. Participants were invited to raise any issues so that management options could be identified, however, none of the participants indicated any concerns.

Summary and limitations of methods

The need to maintain a manageable scope for a Masters-scale research project creates significant constraints for the research methods. A key limitation of this research is its relatively narrow data source, drawing only from interviews with a limited sample of fresh produce supply chain participants. Methods to generate data from wider sources, such as document analysis, could have enriched the research and supported broader generalisations from the interpretation of the results. The research has, however, generated a rich data set which provides valuable insights into the research questions. In the next two chapters, the results of the study are presented, exploring the impacts of recent natural disasters on fresh produce supply chains and how climate risks are perceived and governed by supply chain actors.

Chapter Five: Impacts of natural disasters and constructs of climate risk in fresh produce supply chains

Introduction

Recent research has identified that a capacity for immediate responsiveness to disruptions supports a degree of resilience in Australian food supply chains following natural disasters (Bartos et al., 2012, Smith et al., 2016). Such assessments, however, can obscure the longer term impacts experienced by businesses within food supply chains and have not considered the implications of recurrent natural disasters on food systems. This study aims to address this gap in the literature. This chapter presents findings regarding the study's first two research questions, exploring the impacts and implications of recurrent floods in south-east Queensland for fresh produce supply chains, and supply chain actors' perspectives on recurrent floods and climate risks. Interview data from vegetable supply chain actors demonstrates that the impacts of recent flood events have fallen more heavily on the production and transport end of supply chains, and recurrent natural disasters have caused cumulative impacts that have particularly affected vegetable growers. It is argued that, over time, these cumulative impacts may weaken the fresh produce supply chain, despite its demonstrated capacity for responsiveness and flexibility in the short term. Data from the interviews indicate that while supply chain actors held divergent perspectives on climate risk, shared narratives strongly influence the collective construction of climate risk amongst many in the supply chain. The influence of these constructs on the governance of climate risk and responses to recent disaster experiences will be explored in the next chapter.

The impacts of recurrent floods and implications for fresh produce supply chains

Interviewees' accounts demonstrate that all segments of fresh produce supply chains, from production through to retailing, were impacted by the flood events of 2011 and 2013. This reflects international analysis that found extreme weather events cause significant damage and disruption in both the production and post-production stages of the food chain (Vermuelen et al., 2012). The types of impacts, and the extent to which various impacts were experienced in each segment of the supply chain, is synthesised in Table 5.1. This synthesis demonstrates that the distribution and severity of impacts was weighted most

Table 5.1 Impacts of flood events in 2011, 2013 and/or 2014 on segments of the vegetable supply chain

Impacts of flooding or recurrent floods	Supply chain segment				
	Production	**Packing**	**Freight**	**Wholesale**	**Retail**
Physical impacts					
Crop/product loss or product spoilage	M-H	L-M	L-M	L-M	L-M
Damage to core assets	H	-	M	M	-
Permanent loss of core assets (farming land)	H			-	-
Damage to critical infrastructure	H	-	M	M	-
Interruption to business processes / flow and/or increased costs of business	H	M	H	M	M
Business/financial impacts					
Decline in value of core assets (farming land)	M	-	-	-	-
Lost investment	H	-	-	-	-
Lost income	H	M	M-H	L-M	-
Reduced cash flow	H	M	H	L-M	-
Cost of repairs / replacement of assets	H	L-M	M	M-H	-
Delayed debt repayments	M-H	M	L	-	-
Increased debt	M-H	-	L	-	-
Personal impacts					
Trauma / shock	M-H	M	L	L-M	-
Increased workload	H	M	L	M	-
Fatigue	H	M	L	M	-
Severe stress	H	M	L-M	L	-
Decline in mental health	M	M	L	L	-
Conflict with other supply chain members	-	-	M	-	-

Key: H is high; M is moderate; L is low; - is not reported.

Source: author's synthesis of interviewees' accounts

heavily towards the upstream end of the supply system (vegetable growers, some grower-packers and transport companies). Growers faced the most extensive, multi-faceted and long-term impacts, experiencing damage to crops, soils and farm infrastructure (in some cases across multiple production sites) as well as business, financial, personal and mental health impacts.

This uneven distribution of disaster impacts was even more evident in interviewees' accounts of the consequences of the rapid recurrence of flood events. A number of

vegetable growers and grower-packers reported that the experience of multiple disasters over three years caused accumulating impacts; yet actors from the downstream supply chain (wholesalers and retailers) were less impacted by subsequent events. An analysis of interviewees' accounts suggests that those in the upstream supply chain are more vulnerable to recurrent natural disasters and that this is linked to longer recovery periods and a higher degree of spatial and financial exposure to climate risks and events. Each of these factors is discussed in turn below.

Recovery period from disaster impacts

A key factor that influences growers' vulnerability to recurrent disaster events is the extended time required to repair flood damage and return to full production[13]. While those in the packing, wholesaling and retailing segments of the supply chain indicated they had recovered from most flood impacts within weeks or months, growers needed much longer to repair physical damage to their properties and farm infrastructure. Extended delays in returning to production exacerbated the financial impacts and delayed the recovery of farm businesses. Growers involved in the study described timeframes for repair works in their fields extending from eleven months through to several years. When successive severe weather events strike within a short period of time, impacts begin to accumulate as further damage is done to farm assets that had not fully recovered from the previous disasters. For example, growers described how they had reclaimed farming land after the 2011 events by retrieving displaced top soils from creek beds or neighbouring properties then re-spreading it on fields. These fields were still fragile and unstable when the 2013 flood occurred. Interviewees explained how this flood washed top soils out of the catchment and resulted in permanent loss of farm land in some places:

> … the soil wasn't down the end of the paddock, it was in Moreton Bay - Mark, Grower-Packer.
>
> [after the 2011 flood] a lot of country was raw because it had been washed and re-issued from other areas [then, due to the 2013 flood] … we had blocks that were washed away completely … We saw [other growers'] farms washed away that were land worth $20,000 an acre and it's all gone – Stuart, Grower-Packer.

[13] While most growers have insurance policies that cover farm infrastructure, these do not cover damage to soils and fields, nor do they cover loss of horticultural crops. In contrast, insurance policies would cover most damage and losses experienced in other segments of the supply chain.

> There's basically guys that have lost their entire property … what was once beautiful, wide paddocks on either side, like your alluvial country … don't exist anymore - Anne, Horticulture Industry Recovery Officer.

Growers also described long-term impacts on soil health, in particular, the way recurrent floods progressively strip nutrients from the soil:

> So … we're still not repaired after 2011. … we started to find [our] legs a little bit but then got the [2013] flood… So even though it wasn't as bad, it still did flood over our growing area. It didn't take soil away but what it does take away is the nutrients – Sally, Grower.

Many growers spoke of the emotional toll of flood recovery and the fatigue associated with working hard to repair flood damage, only to suffer more damage from subsequent intense rain and flooding. David, a Fassifern Valley grower who experienced three flood events between 2011 and 2014, described an accumulating frustration and distress:

> Mentally, it was like, fricken hell. You cannot believe [it]. And you knew exactly what needed to happen, it's just you were so exhausted from the first one that to saddle up for another one straight away was bloody ridiculous. I know it seems funny, but that 10 inches that we had in March [2014] where we lost crop, it wasn't probably the physical blow because you didn't have to do the ground work- we didn't lose dirt as much [as the previous two floods]. But it was like, how many times? How often does this have to fricken happen?

These accounts indicate that the recurrence of severe flood events at intervals of one to two years have significantly degraded land stability and soil health across many farms in the Lockyer and Fassifern Valleys, eroding the core productive resources of farm businesses. In addition, the recurrent floods have affected growers' mental health and confidence, resulting in significant fatigue and stress. The extended recovery period for horticultural businesses following a natural disaster, therefore, appears to significantly contribute to the vulnerability of the production segment of the supply chain to rapidly recurring extreme weather events.

Spatial exposure of upstream actors to climate risks and disaster impacts

The spatial exposure of horticultural production and transport businesses to climate risks is another factor that increases vulnerability to recurrent natural disasters in the upstream supply chain. It is recognised that agricultural production, and horticulture in particular, is highly exposed to weather hazards (Deuter, 2008, Edwards et al., 2011, Webb and

Whetton, 2010). Recent trends within the horticultural industry - in particular, growers expanding their area of land under production - have further increased this exposure. A number of growers and grower-packers interviewed in this study described how declining profit margins had driven them to expand their farming area, as larger volumes of produce were needed to generate sufficient income to sustain their families and service debts. In expanding their farming operation, growers often seek to diversify their production sites across a number of climatic zones to extend their seasonal production windows and spread their climatic risks. Growers identified, however, that this strategy presents a 'double edged sword'. Establishing multiple production sites in diverse locations can enable growers to continue farming on properties not affected by extreme weather events. Farming more land, however, can increase growers' exposure to weather hazards, which can result in greater crop losses and higher re-construction costs if multiple properties are affected by natural disaster. Interviewees' accounts demonstrated both of these possible outcomes. Two grower-packers, Leanne and Kate, indicated that diverse production sites had enabled them to meet supply commitments in spite of severe flooding, crop losses and damage on some of their properties because they could continue to grow on their unaffected land. In contrast, Stuart, a grower-packer who operates multiple properties in various regions, suffered extensive damage across several properties from floods in 2011, 2013 and 2014, resulting in significant financial impacts:

> We're farming over 3000 acres of country now so that's just the way it is … we run this risk because we grow 12 months of the year in different areas. We're always susceptible to something somewhere … We do diversify in growing region to minimise that risk. Unfortunately for the last two out of four years it hasn't paid off.

The transport segment of the supply chain is also subject to a high spatial exposure to climate risks, due to its reliance on an extensive road and bridge network. Recent flood events have caused significant disruptions and damage to Queensland's transport infrastructure, resulting in added costs and reduced efficiencies for freight companies as trucks were grounded by floodwaters or drivers took longer routes to avoid road and bridge closures. Rob and Tony described the consequences of the spatial extent of flooding in 2011:

> North of Goondiwindi you couldn't get through. You couldn't get through to North Queensland … several roads on the New England were cut and [the flooding along] the coast road was up and down too. So it was just you had to pick your time. We had trucks stuck [all around] the State - Rob

> Yeah, it was like if you want to go 100kms from A to B you had to go about 1500kms to get there – Tony, freight company.

The high degree of spatial exposure to weather events of upstream businesses in the supply chain relative to those downstream has contributed to the impacts they have experienced from recurrent disaster events. An increasing degree of spatial exposure to climate risks is particular to the production end of the supply chain, and contributed to the accumulation of disaster impacts experienced by a number of growers and grower-packers involved in this study.

Financial exposure of upstream actors to disaster impacts and climate risks

The third factor found to increase vulnerability to recurrent natural disasters is a high degree of financial exposure amongst businesses in the upstream supply chain. For vegetable growers this is linked to a combination of increasing debt and poor returns. Growers' debt levels have increased due to a need to make substantial capital investments (for example, in water efficient irrigation systems and sophisticated packing facilities) and also to fund the purchase or lease of additional properties (Cotter, 2015, DAFF, 2014). Grower-packer, Stuart commented that most large farming businesses are heavily mortgaged. The limited power held by growers in the food system is well recognised in the agri-food literature (Gregory et al., 2005, Lawrence and Dixon, 2015); this research confirmed that vegetable growers face challenges negotiating fair prices with retailers. Poor prices received through the supply chain, coupled with unprecedented increases in growers' costs of production, have resulted in diminishing profit margins in many horticultural enterprises (AUSVEG, 2015). Some interviewees noted that it is not uncommon for vegetable growers to operate purely on cash flow and that many operate for extended periods without making any profit[14]. With high debt and low or no profit, many farm businesses are unable to build up cash reserves. Accordingly, when they are affected by natural disaster events, the only option to fund their recovery is through accessing limited government assistance or additional borrowings, that is, by further increasing their total debt. There are two important consequences of this. The first is that growers who cannot further extend their loans are forced to leave the industry. Anne, an industry recovery officer who worked with many farm businesses following the 2011 and 2013 floods said:

[14] An analysis of the financial performance of vegetable growing enterprises in Australia found "over half of vegetable growers fail to achieve a positive return on their endeavours" (James, 2013, p. 4)

> I've heard from a lot of different people in the industry … [including] rural financial counsellors, that the first [flood] was horrendous and bad, but manageable. People were bouncing back. The second one was the straw on the camel's back for a lot of growers and still some of them haven't recovered, or they're just not even farming anymore … So that second flood was a real catalyst, I think, for a lot of people. Maybe the writing was already on the wall, but it was that one that really made it come to fruition.

The second consequence is that those who can extend their debt are in a weakened business position, with a diminishing financial capacity to pursue disaster recovery works or cope with future extreme weather events. Interviewees further identified that the diminishing viability of horticultural businesses in turn threatens the security of financial institutions:

> The financial strain … with the bank manager was fairly significant because the banks are then getting concerned … They're starting to feel a bit cornered where they don't want to call in their mortgages and take over properties because they're in a mess to start with. But then the whole economy's just going to fall apart - so I think they were trying to strategise how to deal with it all. So it was a very shaky time for us because we got up into a level of debt with the bank that they didn't like – Sally, Grower.

> If you put it together, we're probably looking at a $4 million loss over a period of four years through two natural disasters … Our lending institutions, whilst they've been understandable in the past, I don't think they can sustain that kind of pressure for ever and a day – Stuart, Grower-Packer.

Both freight companies involved in the study confirmed that the transport industry is also characterised by a very high level of debt due to the need to maintain large fleets of trucks. Rob explained the financial consequences of the floods for his business this way:

> No income meant that you're still making [lease payments] on your vehicles. It's … highly geared financially, the transport industry… So the payments every month, multiplied by the size of your fleet … The banks are always good. They'll come to the farmers, they'll come to us and they'll go, "Do you want to defer the payments? We'll let you off for three months". But you've got to pay it … you might as well just keep going, so that's what we chose to do. It was a good 12 months - easy. I still believe today that we struggle from the effects, because the 2011 [flood] and the

> next one was 2013! Like you just breathe a sigh of relief, say “we're there”. We just about got back, next minute: gone again!

Interviewees’ accounts demonstrate that high levels of financial exposure combined with rapidly recurring flood events have caused accumulating financial impacts on vegetable production and freight businesses, driving a growing number of upstream supply chain businesses towards highly risky levels of debt. This, in turn, increases their vulnerability to climate risks in the future.

Implications of the uneven distribution of climate risks and disaster impacts

Interviewees’ accounts provide important insights into the impacts of recurrent floods and the uneven distribution of vulnerability to climate risks in fresh produce supply chains. The study has demonstrated that recent floods have resulted in permanent loss of some productive land, destabilised and degraded horticultural soils, disruptions to transport networks over long periods, and diminished business viability and increased debt in horticultural, freight and some vegetable wholesaling businesses. Studies of the impact of natural disasters on manufacturing supply chains have assumed that businesses in different segments of the chain would be exposed to similar risk and carry similar degrees of financial leverage (Altay and Ramerez, 2010). In contrast, the finding of this research is that in fresh produce supply chains, vegetable production and horticultural freight businesses have a higher spatial and financial exposure to climate risks than downstream supply chain members and are subject to longer term impacts and longer recovery periods from extreme weather events. I contend that the market power of supermarkets, which enables retailers to maintain strong pressure on other members of the supply chain to deliver products and services at the lowest possible price while leaving them liable for most risks, contributes significantly to the higher spatial and financial exposure of upstream supply chain members to climate risks. These findings reflect critical interpretations of natural disasters which argue that the distribution of power and resources in society strongly influences the distribution of risk which, in turn, adds a socially constructed element to natural disasters (Tierney, 2012).

The findings indicate that within vegetable supply chains, the production segment is most vulnerable to climate risk, with growers experiencing accumulating financial impacts and debt, degradation of core productive assets of land and soils, and a heavy emotional toll. Recurrent floods have catalysed the exit of many growers from the industry. Two large scale grower-packers suggested that the horticulture industry in the Lockyer and Fassifern Valleys was now at a tipping point: Kate noted that if flooding continued to occur at this

frequency, farming businesses “could not really be sustained” while Stuart said, “if we were to get two more natural disasters like we had in the last two years, well I think that would probably just about wipe the [growing] industry off the map.” Recent research has found that both long and short agri-food supply chains in Queensland showed a capacity for responsiveness following flood events that aided their resilience and enabled them to continue to support food security (Smith et al., 2016). In contrast, this research finds that while supply chains can be responsive in the face of natural disasters through accessing alternative supplies from unaffected regions and utilising alternative transport routes, recurrent disasters and the uneven distribution of vulnerability to climate risks across the chain have caused accumulating impacts on upstream businesses. The findings indicate that some attributes identified in chapter three as contributing to agri-food supply chain resilience – the capacity to maintain financial reserves and protect core assets – have been comprised following recent flood events. The findings also suggest that the distribution of risk and rewards - another key attribute of resilience – is not equally shared amongst supply chain members. These matters will be further discussed in the following two chapters. This erosion of capacity in the upstream supply chain weakens the fresh produce supply system overall and indicates that supply chain resilience may be at risk in the longer term unless actors in the system find improved means of managing disaster impacts or more evenly sharing climate risks. The ways in which climate risks are governed in the supply chain and the extent to which participants are acting collectively to adapt to emerging climate risks and enhance longer-term supply chain resilience will be explored in the next chapter. This chapter now turns to consider how actors within the supply chain made sense of the recent disasters and their perspectives regarding climate risks into the future.

Perspectives on recent floods and future climate risks

The perspectives of vegetable supply chain members regarding recent flood events and future climate risks offers a means of developing an understanding of how climate risks are socially constructed within supply chains. In this section, the findings of the research regarding how supply chain actors have made sense of recent recurrent floods and perceive future climate risks are outlined, highlighting the powerful influence of dominant narratives of climate variability in Australia. The findings are interpreted to draw out the key factors influencing the social construction of climate risk by supply chain members.

Perspectives on recent flood events and the influence of climate change

The interviews revealed that supply chain members held similar views about the recent floods, though a divergence of perspectives regarding the influence of climate change on these events. When asked about the recent floods almost all interviewees responded that Australia is characterised by a highly variable climate so extremes in weather conditions will occur from time to time which may affect their business and supply chains. This suggests that supply chain actors accept a variable (and sometimes extreme) climate as normal, a finding consistent with previous research regarding the views of rural Australians about climate variability (Buys et al., 2012). Most interviewees drew on this narrative to make sense of recent recurrent flood events. While many indicated that the recent floods were particularly severe, with comments including “it was bad, really bad” (Mark), “probably the worst in his lifetime” (Rob) and “my neighbour said he’d never seen a flood this deep and this nasty” (Sally), interviewees nevertheless held firm to the idea that these events were consistent with their expectations and experiences of Australia’s highly variable climate, as the following comments illustrate:

> You have extreme events and that's how Australia is. The 10 year drought whenever that ended … three years ago? That was an extreme event. But we also had a flood in 1996 – John, grower.

> As farmers, we deal with the weather. That's what we do. I really have no fear of the weather, because I've dealt with weather for the last 20 years. You talk about average years … well, there is no average year. No two years are ever the same. You have to deal with that. That's life, in our world - Mark, pack house manager and grower.

Varied perspectives on climate change and its influence on recent flood events, however, emerged from the interviews. Some interviewees were emphatic in their view that climate change was not a factor in the recent extreme weather events, and that the recurrent floods were not indicative of emerging risks linked to climate change:

> I believe in sustainability and leaving something there for generations behind us, but… I believe that climate change is a massive beat-up - Alex, wholesale agent.

> I take a lot of it with a grain of salt, personally. Are we accelerating a weather change? I wouldn’t have a clue… It’s a cycle. It’s a cycle that [comes back around] over millions of years - Graham, freight company owner.

Others drew on memories or records of past weather to question the suggestion that the recent flood events may indicate a change in climate. For example, grower David commented:

> It's a tricky one, I don't know. If you were a believer in climate change, then you're going to say well that's a beautiful example of it. But in the 70s this happened: like in '74 it happened, in '76 it happened, and then it happened in '82. When you look at our rainfall data it's not like it hasn't happened before, it's just that it's probably not the investment in infrastructure that they had then. They just didn't have as much to lose - David, grower.

A number of interviewees indicated that the floods were significant not because of how quickly they had recurred, but because they coincided with a rapid escalation in capital investments and the cost of key inputs such as electricity and fuel which intensified the cost-price squeeze experienced by growers, packers and wholesalers. Alex, a wholesale agent said:

> You know, all the floods and the disasters and everything are devastating, but when you speak to the producers, they've been through all that stuff before. What they haven't been through before is massive price rises, cost of farming…. coincidentally it all happened the same time as … the natural disasters.

Making sense of the recurrent flood events through reference to expectations and experiences of Australia's variable and extreme climate - rather than scientific claims of climate change - reflect Granderson's position that "where changes are perceived as within the realm of past experience, anthropocentric climate change may not appear as a significant risk that warrants shifts in practice or knowledge" (2014, p. 59).

Some interviewees, though, while expressing some uncertainty about the idea of climate change, felt it may have been a factor in recent weather events or may be influencing climate risk:

> Yeah, it's a hard one because who do you believe these days? … I don't know about global warming but I know we're putting a lot of pollution into the air and that's got to be affecting the weather or what happens - Chris, organic wholesale agent.

For others, the experience of multiple severe floods within a short period appeared to have somewhat unsettled their understanding of climate risks and the dominant narrative of climate variability, leading them to wonder if extreme weather events were occurring more frequently or that climate risks to their business were increasing:

> We were told in 2011 that was a one in 100 year phenomenon and two years later it happened again. So what's around the corner? We don't know - Stuart, large grower-packer.
>
> Yeah, heaps. Changed the way I think about future weather risk. Changed the way I think about farming - Michael, grower.

While acknowledging the role of climate variability, a small number of interviewees actively incorporated their knowledge of climate change into the ways they made sense of recent flood events:

> My take on it all is that the climate change research is saying that your extremes will be more extreme. So my take is: that's what's been happening. But it's not just in the last three years. It's in the last 20 - John, grower.

These findings suggest that a shared narrative amongst supply chain actors regarding climate variability normalises extreme weather events and has powerfully shaped the ways in which interviewees made sense of recent recurrent floods, resulting in most seeing these events as consistent with the climate risks that can be expected in the fresh produce supply system. Interviewees' perspectives demonstrate how existing frameworks of meanings (in this case, the climate variability narrative) operate within the social network of the supply chain to filter techno-scientific claims regarding climate change and increasing risks of extreme weather (Lockie and Measham, 2012). They also demonstrate the ways that memories (and in this case, records) of past weather are used to help make sense of current weather events (Granderson, 2014). However, as Granderson also points out, the lived experience of weather events (or the embodiment of climate risks) also shapes how communities construct shared meaning regarding climate risks. This suggests that those interviewees who were questioning whether recent recurrent flooding may indicate shifting climatic patterns may, in time, influence a shift in shared understandings of climate risk in the supply chain.

Perspectives on future climate risk

Following from the varied perspectives amongst interviewees on the influence of climate change on recent weather and flood events, highly divergent perspectives were also found regarding future climate risks. Three alternative perspectives were identified.

The first perspective, held by the majority of interviewees, was that future risks are not expected to be significantly different from those experienced in the past. This view was strongly linked to the dominant narrative of climate variability and interviewees who held

this view tended to be skeptical of the notion that climate change was influencing climate risk:

> It's just part of what happens. You can't predict the weather ... But every year is different and the old rule is you have one good year in five, being a farmer and there is one year in five where you have a shocker … It's just risk - Tim, wholesale agent and grower.

> I don't think I'm going to get another major flood in two more years. I hope not…Look if I had to live with thinking that that was going to be the way it was, we wouldn't bother – Mark, grower-packer.

A smaller number of interviewees expressed a sense of unease that climate risks may be escalating and may no longer simply be associated with normal climate variability. For them, future climate risks were uncertain and the link to the dominant climate variability narrative was weakening. Actors who expressed uncertainty regarding future climate risk also indicated that their approaches to climate risk management may require some adjustment:

> Yeah I think it has actually [changed the way I incorporate weather/climate risk into future business plans]… I suppose there's a realisation that our returns need to be significantly higher for what we do, to be able to sustain the kind of damage that we have, when it is going to keep returning, keep recurring - David, grower.

The third perspective was based on the view that climatic variability will play an on-going role in shaping climate risks but also included a clear expectation that climate change would increasingly influence weather conditions. Actors who held this view spoke with clarity about the changes they anticipated in climatic conditions, identifying factors such as increased climatic variability, a greater likelihood of extreme weather events, overall warming and an increased occurrence of extreme heat conditions. For example, Simon (spokesperson for supermarket B) said:

> I definitely think there is a change in climate... I think a lot of the seasons from my understanding are probably going to get more variable. So you may have more likelihood of really extreme weather - whether it be more frosts or more extreme heat days - with a general increase in the average temperature.

Neil, a financial counsellor, indicated that those of his clients who anticipated increasing climate risks believed that it would be necessary to prepare for, or adapt to, the emerging risks:

> …some people that I talk to say oh, yeah there is a change in the climate, we're noticing that with a lot of the things that are happening out in the paddocks …. They'll be factoring it in and saying okay, what do we need to do to manage the risk? We're in an area that's going to cop it if [extreme weather] comes again. We can't prevent it so what are the things that we can do to try to bring that from a catastrophic outcome back to a medium outcome? Because there'll be a loss.

A summary of the three alternative perspectives on climate risk held by the participants in the study is presented in Table 5.2. These findings are consistent with studies of US corn farmers, where most did not believe climate change posed a risk to agriculture, others were uncertain, while a few perceived increased risks (Stuart et al., 2012). The table demonstrates that actors who anticipate increasing future climate risks are located in the growing, packing, and retailing segments of the supply chain, suggesting that while it is not the dominant view, it is not isolated to one position in the supply chain.

Table 5.2 Perspectives amongst supply chain participants regarding future climate risk

	No significant change in climate risk expected; expect continued climate variability	**Climate risk is uncertain but may be increasing; risk may no longer be driven only by climate variability**	**Climate risk is increasing; risk will be driven by both climate variability and climate change**
Growers/Packers	Mark Kate	David Stuart Sally/Michael	Rachel/John Liz/Peter
Transport & logistics	Rob/Tony Graham	Scott	
Wholesalers / supply chain intermediaries	Alex Tim George	Chris	
Retail			Simon

Source: Author's interpretation of interviewees' perspectives

The social construction of climate risk in fresh produce supply chains

These findings suggest that both experiences of, and narratives about, climate variability are central to the social construction of climate risk amongst supply chain actors. Granderson (2014) found that dominant discourses and community-level narratives had an important influence on the production of shared meanings of weather events and collective understandings of climate risk. While the interviews indicate that personal experiences of

climate variability helps to shape risk constructs, the shared narrative around climate variability, voiced by most research participants, appears to powerfully influence a collective construction of climate risk amongst actors in the supply chain. This collective construct appears to normalise and attenuate the risk. The findings also suggest, however, that the lived experiences of rapidly recurring weather extremes and flood impacts as well as knowledge of climate change projections have catalysed some supply chain members to begin to re-construct climate risks and shift away from the collective construct. These actors problematise, or are beginning to problematise, the climate risks at play within the fresh produce supply system. This may better position them to anticipate and respond to emerging risks of increasingly intense and frequent extreme weather events (Davidson 2012, Granderson 2014). The evidence that this re-construction of climate risks is occurring with actors situated throughout the supply chain further opens the possibility for system-wide as well as individual responses or adaptations.

This research provides some important, though preliminary, insights into the social construction of climate risk amongst actors in fresh produce supply chains. The study, therefore, offers a contribution to knowledge of the lived experience and social construction of risk arising from climate change, for which there is a very limited body of literature (Carolan, 2010, Granderson, 2014, Zehr, 2015). Further, more focused, research to investigate the diversity of factors that contribute to supply chain members' risk constructs would be valuable. In particular, there is significant opportunity to more deeply explore the process of collective risk construction within agri-food supply chains.

Conclusions

This chapter has address the first two questions of this study: what have been the impacts, and implications, of recurrent floods in south-east Queensland on fresh produce supply chains, and how have supply chain actors made sense of recent flood events, and in what ways do they construct climate risks? Supply chain actors' accounts demonstrate that recent floods have done long-term damage within fresh produce supply systems, with significant impacts experienced by businesses in the upstream supply chain. Recurrent floods have degraded core productive assets on farms, forced horticultural and freight businesses to add to already risky levels of debt, depressed productivity and business performance for extended periods, and increased stress and fatigue amongst growers. Since the floods, some growers have left the industry and even large-scale businesses that remain are described as being at a tipping point. It appears, therefore, that the fresh

produce supply chain has been weakened by recent natural disasters. The uneven distribution of climate risks within the supply chain means that production and transport businesses are now highly vulnerable to future extreme weather events, and this potentially threatens the broader chain. Many interviewees expressed confidence that supplies of fresh produce can always be sourced from somewhere in Australia. Climate trends occurring nation-wide towards increasing intensity and frequency of extreme weather events, however, together with the findings of this study, suggest that fresh produce supply systems will be subject to increasing risks into the future and are becoming increasingly vulnerable to those risks.

While interviewees acknowledged the severity of recent disaster events, most constructed the recurrent floods as within their expectations of Australia's highly variable, and sometimes extreme, climate. Only a few attributed the rapid recurrence of extreme weather events to the influence of climate change. Similarly, most interviewees constructed future climate risks through the dominant narrative of climate variability and did not, therefore, anticipate that the risk of extreme weather was increasing in the fresh produce supply system. This indicates that amongst most supply chain actors, the collective construct normalises and attenuates climate risk. A smaller number of interviewees, however, influenced by recent experiences and/or climate change discourses, were beginning to question the dominant narrative and constructed future climate risk as uncertain. A final construct, held by a limited number of interviewees from each segment of the supply chain, was that climate risk was increasing in the future. Within these latter two groups, climate risk was increasingly being problematised and some actors indicated that the perceived shift in climate risks would require active management or adaptation. The extent to which the research participants are responding to climate risks, and the ways in which climate risks are governed within supply chains, are discussed in the next chapter.

Chapter Six: The governance of climate risk and responses to climate impacts within supply chains

Introduction

The research findings presented in the previous chapter provide insights into the implications of recurrent natural disasters for fresh produce supply systems and how climate risks are perceived and socially constructed by supply chain actors. The thesis now turns to the next two research questions: how are climate risks governed within supply chains? And in what ways are supply chain actors responding to disaster events and emerging climate risks? The theoretical concept of risk governance provides a lens through which the research findings are analysed.

The first section of this chapter presents findings which demonstrate the ways in which actors in fresh produce supply chains govern climate risks and shows how food system structures, supply chain relationships and risk constructs influence this. It is shown that in most supply chains climate risks are governed through the individual actions of participating businesses. There is, however, evidence within some supply chains of cooperative approaches to managing climate risks that are partly consistent with the principles and processes of risk governance outlined in chapter three. In the next section, supply chain actors' responses to recent natural disasters and continuing climatic risks are presented. It will be shown that many of these responses reinforce an individualised approach to governing climate risk in supply chains, but that across a variety of supply arrangements some efforts are being made to enhance collaboration or to seek more equitable distributions of risks and profits.

Contrasting approaches to governing climate risk in fresh produce supply chains

Interviews with supply chain participants revealed two starkly contrasting approaches to the ways in which climate risks are governed in Queensland's fresh produce supply chains. The most commonly described approach involved each business within a supply chain taking individual actions to manage its own risks. The less commonly described approach operated at a whole-of-supply chain level and was described by participants who

have actively sought relationships with supply chain partners willing to pursue collaborative approaches to risk management. These findings are discussed in detail below.

Individualised governance of climate risks

From the interviews it was clear that in most supply chains the governance of climate risks was highly individualised. All interviewees described strategies they applied within their own business to manage climate risks. Importantly, the majority indicated that they expected that each member of the supply chain would manage their own risks and that they did not seek to work with others towards collective management of climate risks through the chain. Some interviewees responded that they could not see how it would be possible to collectively address climate risks within supply chains. Rob, from one freight company said, “I don't know how you'd pull all the industry segments together: government, farming, transport, your essential services”. Similarly, Graham, owner of another freight company, firmly argued that climate risks can only be managed through individual business strategies:

> I don’t know how you could [collectively manage or share climate risks]. They’re all individual businesses. We are all part of the supply chain, but they’re individual businesses.

Interviewees’ accounts suggest that climate risks are typically governed within fresh produce supply chains through the independent and separate actions of individual businesses taking responsibility for the management of their own risks. This individualised approach to governing climate risk appeared to be particularly associated with supply chains that utilised the wholesale market system and those based on direct supply relationships between grower-packers and supermarkets. Following Gereffi and Lee (2012), the governance arrangements in these styles of supply chains can be described as market or modular, respectively[15]. Research participants described these supply chains as loosely connected, highly risky and exploitative (see Table 6.1) - characteristics that limit opportunities for supply chain members to engage in meaningful dialogue regarding risks, develop trust-based relationships, or consider options for collaborative management of climate risk across the chain.

[15] As outlined in Chapter two, under market-based governance arrangements, transactions are relatively simple, there is an arms-length relationship between buyers and suppliers, and price is the central mechanism of governance. Modular networks involve buyers setting specifications for suppliers’ products and some exchange of information regarding standards.

Table 6.1 Key characteristics of market and modular supply chains

Supply chain characteristics	Actors' perspectives
Loosely connected	We've got no agreements with them [the supermarkets]. Yeah, it's just an arrangement. Tim, wholesale agent It's a very informal relationship [between the pack house and grower-suppliers]. So we have to have certain things done to satisfy our QA but essentially we don't have any legally binding contracts with people. Mark, pack house manager We're actually quite a big supplier to [Supermarket B]. No one knows that. [Supermarket B] doesn't even know that. John, grower (supplier to large grower-packers)
Financially risky	You never really know if there is going to be a market for your product and you can't be sure of the price you'll receive. That's why they call it 'farming lotto' – it's gambling really. Kate, large grower-packer Some of our bigger producers now that supply us could be extended up to $2 million before a single product has been picked. If you said to someone go up to $2 million on a table at the casino they'd think you're mad. It's basically that. Alex, wholesale agent
Exploitative	That culture in the [wholesale] market system … most of the guys do business in a way that if they've got power, they'll take the most advantage of what they can get. That's just been the nature of how it's worked, rather than try and build each other's business. It's very much a take-advantage-when-you-can situation. Peter, large grower-packer It's simply a case of: we all need what we need out of the system and no-one seems to have me in their interests. It's just, "Ok it's what I need. I don't care what you need. You're going to keep getting up every day and supplying me. That's your problem, not mine." So, you've got this, "Oh, he'll put up with it [mentality]." Michael, grower-packer, describing the attitudes of wholesale agents Everyone has got their customers they serve every week and the market goes up, the market goes down. But if someone rings up out of the blue that we don't normally deal with and says, "oh, can I buy some lettuce?" … personally, I think "what's happened to their regular supplier?" Then the next thing you're thinking about is, "I wonder how much we can charge him?" Tim, wholesale agent

Source: Author's analysis drawing from interviewees' accounts

From interviewees' accounts of modular supply chains, it appears that supermarkets tend to encourage and reinforce individualised approaches to governing risk through their purposeful selection of (only those) suppliers who can demonstrate sound climate risk management. Asked whether his company pursued whole-of-supply-chain strategies to address climate risks, Simon, spokesman for Supermarket B, said, "To be honest, we don't … we want to work with the better growers who will have those risk mitigation strategies in themselves". He further explained:

> That is something that I do look at when I'm out visiting farms … How likely a hail zone is this? Do they have all their orchards under hail netting? Or do they have protected structures in certain crops? So there are risk mitigation things that we look for … We don't actively go and say to someone, "Look, you need to grow somewhere else to ensure supply". We sort of let them naturally choose what they're going to do …because each business will have their own strategies.

Simon indicated that one way in which his company supported climate risk management in the supply chain was that when suppliers were affected by natural disaster events, Supermarket B avoided "chopping and changing suppliers". He commented that:

> [we continue] buying from our affected suppliers, so they can recover from events like that… That is one thing that we'll do, is support suppliers who have supported us… so I'd say, "look, you don't have supply available, we'll get it from somewhere else for the moment, but then when you are back in supply, we'll resume business".

Suppliers to supermarkets, including the large grower-packers involved in the research, however, expressed a complete lack of confidence in such a commitment. Suppliers shared a very strong concern that an inability to fulfill supply commitments would result in losing their relationship with major retailers – which strongly indicates that the weight of risk associated with climate-related supply chain disruptions rests largely with suppliers.

Individualised approaches to governing climate risk were often also associated with reactive and opportunistic responses to weather conditions. Participants in market-based and modular supply chains described how they actively seek to exploit weather events as they occur and affect patterns of supply and demand in fresh produce markets. Growers and wholesalers spoke of endeavouring to survive times of high supply and low market prices by seeking to optimise profits when a weather event has reduced normal supply levels and pushed market prices higher. For growers, this also involved opportunistically planting when others are impacted by a weather event, with the aim of earning high

returns on an under-supplied market. This strategy, however, is also understood to potentially exacerbate business risks, as grower John, noted:

> you try and take advantage of that supply chain opportunity [but] … after 2011 … everyone did [get a crop back in as quickly as possible] … and the prices just crashed.

Persistently low market prices for fresh produce appear to drive this approach. This is illustrated by wholesale agent and grower, Tim's comments:

> There has got to be a weather event somewhere and prices have got to go up. Whether it's us getting hit or the neighbour or the bloke in Victoria … we can't be sustainable on the prices we get probably 80 per cent of the time … when things get short because of weather or water or drought or whatever…. The price goes up. And we've got to get that better margin, because if people could pay 99 cents for a lettuce all year around, we would last 12 months. You can't survive on that. No-one can.

These findings indicate that in both wholesale market-based supply chains and direct supply arrangements between grower-packers and supermarkets, climate risks are most commonly governed according to a market mechanism, driving an individualised, reactive and opportunistic approach. This reflects neo-liberal principles that encourage individual responsibilisation for risk and security (Chandler, 2013, Lawrence et al., 2013, Rogers, 2013) - yet increases these actors' vulnerability to climate risks and disasters. Further, actors' insights suggest that within these supply chain arrangements there are strong barriers to collective assessment, discussion or decision making regarding climate risks and therefore little opportunity to pursue collective efforts towards climate risk governance.

Collaborative governance of climate risks

An alternate approach to governing climate risks in supply chains, however, was evident in the accounts of a small number of interviewees. Participants in this study confirmed the trend towards direct supply relationships between food producers and supermarkets documented in the agri-food literature (Edwards et al., 2011, Lawrence and Dixon, 2015, Seth and Randall, 2005, Parsons, 1996) and highlighted the implications of this shift for a declining central wholesale market system. The interviews identified that the entry of major

new players in Australia's food retail landscape[16], the rise of direct supermarket supply relationships, and the diminishing role for traditional wholesaling agents over the last decade has provided a platform for the emergence of a new form of supply chain intermediary: the packer-marketer. These companies have evolved from either traditional wholesalers or large-scale growing enterprises, and now play increasingly important roles in directing specialised forms of growing, packing, consolidating, logistics, product innovation, marketing and relationship brokering with large scale customers to supply both the food services and food retailing sectors. The emergence of packer-marketer facilitated supply arrangements has fostered closer connections between participating businesses and supported the development of relational supply chains in the fresh produce supply system[17]. I contend that these relational supply networks enhance the capacity for supply chain partners to establish risk governance processes and enact more effective responses to climate risks in supply chains.

Interviewees involved in packer-marketer facilitated supply chains identified a range of drivers for their move away from wholesale market-based or direct to supermarket supply arrangements. These included a desire to work cooperatively with supply chain partners; the aim of building a critical mass of high quality supply; an interest in product or marketing innovation; and, importantly, a perceived need to more effectively manage climate risks. Reflecting this, clear contrasts were evident between packer-marketer facilitated supply chains and market and modular arrangements. First, they featured a shift away from supply of commodity-style produce towards more specialised, customised or value-added products. Second, participants in these supply chains reported higher levels of trust and significantly more collaboration with their partners. Regarding his packer-marketer company's relationship with its grower-suppliers, George commented, "We prefer to think of [our growers] as strategically aligned partners. Without them, we can't succeed". Peter described the relationship between his grower-packer business, his packer-marketer and Supermarket A in this way:

> We work really closely, we've got an open-book type of relationship … We believe in the value chain that we're in and we think there's a lot more margin come back to us as a grower ... It adds a lot more value and we've got a lot more opportunity to

[16] While Woolworths and Coles maintain a dominant market position, the growth of super-IGAs and the entrance of international retailers ALDI and Costco has diversified the number of supermarket players in Australia's food retailing sector.

[17] As outlined in Chapter Two, relational networks are characterised by a higher degree of buyer-supplier coordination around more complex standards, requiring greater interaction, knowledge sharing, social ties and trust (Gereffi and Lee, 2012).

> contribute to the supply chain. We're not being dictated to. We're listened to in regard to what we believe adds value to the chain… It's a different dialogue to what farmers are normally used to…

Thirdly, in place of a fatalistic and reactive approach to climate risk, these chains featured a more active and anticipatory style of risk management, pursued through multi-faceted strategies operating across the supply chain. Interestingly, those involved with the two packer-marketers identified through the research as pursuing collective approaches to governing climate risk followed different climate risk constructs. George did not consider that the risk of extreme weather events was increasing, instead expressing the view that Australia's normal climate variability posed significant enough risks to seek more effective approaches to their management. Yet, Peter, a large grower-packer aligned with another packer-marketer, anticipated further extreme weather events and believed that climate risks were increasing.

Interviewees described a suite of strategies applied within packer-marketer facilitated supply chains to manage climate risks. The first was the establishment of a broad network of grower-suppliers located in diverse geographic locations, supported with technical and agronomic advice. With their extensive supply network, packer-marketers are able to adapt their sourcing for major orders from one production district to another as required, and avoid disruptions caused by adverse weather events:

> There's that teamwork that goes with us [our consortium of suppliers through the packer-marketer]. If we've got a [weather] event happening that isn't so good, we can then discuss it with [our marketer], that we're not going to be able to supply. They can get it from their suppliers [in Victoria]… so the supermarket isn't missing out … They're just getting product from somewhere other than where they first expected ... So we try and help each other out …It's not that we're versus all those out there. We're working together to make the supply chain work - Liz, grower-packer.

The second key strategy in these supply chains was to expand the volume of production grown in protected cropping systems. George commented:

> Australia's climate is characterised by both extreme weather events and long dry spells so a central part of our business model is to specialise in high value crops that can be grown in protected systems. We increasingly want to move to protected cropping and we have worked to develop products and markets for products that we

> can implement some form of protection for. Doesn't have to be glass houses - can be netted structures, tunnels ... Protective structures aren't a guarantee of resilience either, but they do help.

The third key strategy was to form close relationships with major retailers. While packer-marketers have established relationships with all of the major supermarkets, the degree of alignment each supermarket chooses to develop with packer-marketers appears to vary significantly. Interviewees noted that some supermarkets continue to maintain a large number of direct grower-suppliers, while others have consolidated to just a few for each product line. One supermarket, in particular, had significantly consolidated its suppliers and established strong relationships with packer-marketers, as Peter explained:

> Well [supermarket A] were instrumental in changing their supply chain to be more strategic, building viability into their suppliers, becoming much more closely aligned with the people that are doing things the way they want to do it. So they consolidated; in our lettuce category, went back from 20 [suppliers] to two or three … [that] changes the balance of power a lot.

Interviewees involved in packer-marketer facilitated supply chains noted that their closer relationship with supermarkets enabled more open dialogue and collaboration between supply chain members, enhanced trust, and improved growers' business viability through access to secure, high volume markets. They explained that superior management of climate risks was central to their positioning with retailers:

> That's why we're with [our packer-marketer] so that we've got exposure in different regions. We pitch that supply chain [to retailers] as being the most efficient supply chain that you can have, with the best country and the best areas, best systems, best growers. But hey, you're not going to get it at lowest market value. There's a cost involved on it, if you want us to be [your key supplier] - Peter, grower-packer.

Interviewees accounts demonstrate that a key strength of these supply chains is the ability of packer-marketers to negotiate better prices with supermarkets by offering specialised or exclusive products and coordinating a critical mass of reliable suppliers:

> The more individual players there are trying to supply the supermarkets, the greater position of power the supermarkets have. You don't have to be a mathematician to work that out – they will just play everyone off against each other - George, packer-marketer.

> So our returns into chain store are about ten per cent better on average … to what we get in the [wholesale] marketplace. It's ridiculous! And when you build into the scale that we are, ten per cent on what we do: you retire on that stuff! - Peter, grower-packer.

For the grower-suppliers aligned with packer-marketers, the improved prices generated higher profit margins and a greater financial capacity to recover from the impacts of extreme weather events. The increased security of the relationship with supermarkets was a key factor that provided greater confidence to pursue further investment in climate risk management strategies, particularly protected cropping systems:

> So if you look at any of the high-value protected cropping systems, every one that's done is aligned to a chain store. Not one has done it to sell into the [wholesale] marketplace - because it starts at that [retail] end. You've got to get a commitment from a chain store - Peter, grower-packer.

The interviews also revealed that, in some cases, the collaborative approach to climate risk management in packer-marketer facilitated supply chains extends to supermarkets' consideration of co-investment in protected cropping systems. Peter commented, "They will. They are. They're asking to…" and indicated that he has commenced discussions with the retailer on these options. George, however, had a contrasting view on the issue of co-investment:

> Oh well, [Supermarket A] has invested in helping a grower down south somewhere build some tunnels for his strawberry crop … they're doing a little bit, but they're just playing around the edges really. As a company we don't want that anyway. All we want from them – we'll make the commitment, we'll do what's needed to be done – if they've given us a strategic commitment for a period of time that they're going to buy the product ... We don't want their money – we just want their purchase orders.

George's comment reveals an important insight. Interviewees' accounts demonstrated that while supermarkets play an important enabling role, they are not the driving force behind the shift to more collaborative approaches to governing climate risk in fresh produce supply chains. Despite the development of closer, more open relationships and enhanced climate risk management in packer-marketer facilitated supply chains, the interviews demonstrated that supermarket practices constrain the collaborative governance of risk in several significant ways. First, while growers in these chains did report higher profit margins, interviewees commented that pricing negotiations were always fierce and the

supermarkets maintained a counter-productive emphasis on low prices. Second, the common practice within supermarkets of rapidly moving personnel through various positions in the company significantly impacted the capacity to sustain shared knowledge, decision-making and trust based relationships:

> You go to a strategy meeting and set the path for the next two to three years… and turn up at the same meeting 12 months later and there's two or three new faces in the room and they're hearing what you are telling them for the first time! Now you'd have thought whoever they'd taken over from would've briefed them. Believe me, that's a real challenge - George, packer-marketer.

Finally, interviewees did not have strong confidence in supermarkets' long term commitment to relationships with packer-marketers and the more collaborative approaches to risk management. While Peter indicated a highly positive experience with his supply chain arrangements over the last five to six years, he understood that its maintenance hinged on the support of the supermarket's top management, and could be abandoned at short notice:

> No. If they get a new CEO tomorrow - if their results don't line up and they start to lose market share – and a new CEO comes in and goes, "hang on, we've got to be more price competitive" ... If they perceive their suppliers as not being competitive - well that's the risk.

Prospects for climate risk governance in fresh produce supply chains

The findings presented here offer valuable insights into the various ways climate risks are governed in fresh produce supply chains. It is interesting to note that certification schemes - the key governance mechanism used to address food safety, quality, environmental and ethical risks in supermarket supply chains - do not appear to be utilised to address climate risk. The findings of the research suggest that individualised approaches to governing climate risks are strongly embedded in many fresh produce supply chains in Queensland. The findings also suggest that processes of risk governance - described in the theoretical literature as involving deliberate efforts amongst diverse actors to collect and consider information on risks and develop collectively binding agreements on how to regulate those risks - would be difficult to establish in many fresh produce supply chains. This study has found both attitudinal and structural factors in market-based and modular supply chains that impede risk governance: that few actors perceive climate risks to be escalating; the shared view amongst many that risks can only be addressed individually; the looseness of

connections between supply chain partners; and the tendency to engage in exploitative or opportunistic behaviours. Together, these factors strongly limit action in the inter-organisational domain and provide poor foundations for the establishment of risk governance processes.

The closer connections between partners in relational supply chains facilitated through packer-marketing companies and their active management of climate risk, however, suggests that there is some potential for climate risk governance to occur in the fresh produce supply system. The findings from these supply chains appear to at least partially reflect van Asselt and Renn's (2011) framework, which suggests that effective structures and processes for governing risk should optimise communication, inclusion, integration and reflection. Interviewees' accounts indicate that in some packer-marketer facilitated supply chains, there are greater opportunities for dialogue amongst partners, more explicit acknowledgement of the need for proactive management of climate risk, more evenly distributed decision-making power, negotiation of trade-offs between security of supply and the price of produce, and even the emergence of co-investment in climate risk management strategies between supply chain partners. It is also clear, though, that climate risk governance is still emerging and, even in these supply chains, significant limits and barriers exist that impede its development. Also, as van Asselt and Renn (2011, p. 440) point out, "as the term governance implies, analysing and managing risks cannot be confined to private companies or regulatory agencies". This analysis has focused on the private governance of climate risks in the supply chain – and begs the question: what roles might the state play? The involvement of government in the recovery process following recent flood events was raised by a number of research participants and will be discussed in the next section. Drawing on these findings, the potential role of the state in climate risk governance in fresh produce supply chains will be considered at the conclusion of this chapter and in the final discussion.

Responses to natural disasters and future climate risks in supply chains

Supply chain members' descriptions of how they have responded to recent flood events and future risks offer another perspective on the governance of climate risks, and may indicate emerging shifts in governance arrangements catalysed by recent disaster experiences. Through the interviews, participants discussed their immediate and short-term responses to recent flood events and reflected on how the floods had reinforced

some existing industry trends but also catalysed some action towards more significant adjustments in their businesses or supply chains.

Interviewees' accounts demonstrate that during and immediately after recent flood events, near-universal efforts were made by growers, packers, transport companies, wholesalers, marketers and retailers to limit disruptions to supply and, as far as possible, to maintain 'business as usual'. This included applying transport contingency arrangements, replanting flooded fields as quickly as possible, accessing alternative production or wholesaling sites, wholesalers and retailers finding alternative suppliers, and retailers relaxing product specifications or sourcing arrangements. In the weeks and months after the floods, interviewees in all segments of the supply system described how they translated the lessons learned from their disaster experiences to implement adjustments within their business that aimed to strengthen their capacity to avoid or reduce impacts from future flood events and minimise the period of business disruption. These responses included re-designing farm drainage systems and levy banks, raising the height of motors for refrigeration or air conditioning units, raising the level of new buildings, adjusting the set-up of wholesaling facilities, making more use of seasonal weather forecasts, more actively monitoring and managing fuel reserves, and developing more stringent response and contingency plans. The actions interviewees described focused primarily on mitigating their own business risks and boosting their own competitive advantage. This suggests that the immediate and short term responses to recent recurrent flood events have further reinforced the individualised approach to governing climate risk in fresh produce supply chains.

Many interviewees commented that recent flood events had provided further impetus for some established industry trends. For example, the floods and perceived future climate risks confirmed for many the necessity for growers to diversify production sites and for wholesalers, marketers and retailers to diversify their supplier base. Some noted that the vegetable growing industry had further consolidated into a smaller number of larger-scale growers, as less viable growers heavily impacted by recurrent disasters were forced out of production. Some felt that the risks extreme weather events continued to pose in the supply system would strengthen the trend towards protected cropping systems, though the costs of implementation, the poor returns for fresh produce, and the limited number of products that could be grown in protected systems were noted as a constraint on this trend.

The interviews also revealed, however, that some more systemic responses to climate risks in fresh produce supply chains have emerged following the recent flood events, including efforts to enhance prices, address the distribution of climate risks, and seek more effective support or interventions from governments. Each of these is discussed below.

Efforts to achieve sustainable prices for fresh produce

The first strategic response evident amongst supply chain members following recent flood events was an increased drive to act on long-standing concerns that the price received by growers for fresh produce is insufficient and unsustainable. As grower-packer, Sally said:

> Can we fix the real problem? The base problems are the returns that you get. People undervaluing food and thinking they should get it for nothing and the people in the middle making all the money. I mean these are the real issues…

David, a grower who supplies two pack houses, described his response to the impact of three damaging weather events over three years:

> It led me to question what the hell we were doing, to be honest … It probably led me to be more aggressive in terms of our pricing negotiations, because it's out of pure desperation that you're going to end up doing all of this for nothing if you don't value what you do, or what you produce, more.

The financial impact of recurrent floods on many businesses, particularly in the upstream segments of the supply chain, appears to have catalysed a strengthened resolve amongst some growers, packers and wholesalers to actively pursue strategies to improve their profit margins. These actors recognised that without adequate margins there was no capacity to build sufficient financial reserves to recover from extreme weather events or manage for future climate risks. Large grower-packer, Stuart, observed:

> There is a future but certain things have got to change. Right across the board the industry has to become more profitable, more viable… I would love to say I've got x amount of money over here put aside for a natural disaster… but there's just not the fat in the business to do it.

Interviewees described a number of strategies being pursued to achieve higher prices for fresh produce since the floods. For some, efforts were focused on seeking improvements within their existing supply chain; these actors reported renewed pricing negotiations between growers and pack houses and also between pack houses and retailers. Others were seeking to establish at least one additional major overseas customer to reduce their reliance on Australian supermarkets and re-balance the power relations between suppliers

and Australian retailers. Wholesaler, Alex, however, was seeking to re-direct a high proportion of his business towards diverse customers in a number of export markets. He noted that strong trust-based relationships with suppliers, effective communication, transparency in decision-making, and an equitable distribution of profit between partners was essential to the success of this strategy. Still others described how recent natural disasters had contributed to their decision to make significant changes to their business model in order to achieve higher profit margins. Insights regarding these diverse strategies are presented in Table 6.2.

In the first year or so following the floods, interviewees' accounts indicate that Australian supermarkets were responsive to some calls for improved pricing arrangements. Mark, a pack house manager, described his team's pricing negotiations following the 2013 flood:

> We went to Coles and Woolworths … and said 'look, this has been pretty disastrous for us and our growers. We'd really like to set the price this year at this, and not deviate from it. We don't want to take payment specials… we're really going to need this to get back'. Both held to that for last season, which was pretty cool ... That allowed us to pay back to our growers a bit extra. That helped everybody with recovery.

Mark indicated, however, that not all suppliers would be in a position to negotiate such a commitment. This was confirmed by large grower and packer, Stuart, who described Supermarket B as "understanding" rather than "helpful" and that "they're certainly not saying, 'well when you start back up we'll give you $1 extra for your product and that should help ease the blow'".

The interviews demonstrated that progress made towards more sustainable pricing arrangements in supermarket supply chains was short-lived and competitive pressures were re-asserted within one to two years. For example, grower David said:

> I just thought for a while there … there might have been a real genuine change. But in the last three or four months, with some of the negotiations that [our pack houses] have had, it's just been plainly obvious that whatever goodwill or determination to do it otherwise [has] just evaporated.

Table 6.2 Strategies to improve prices and profit margins following floods

Strategies to improve prices and profit margins for fresh produce	Supply chain actors' perspectives
Negotiations amongst existing supply chain partners for pricing arrangements that enable suppliers to build financial reserves.	"It's made me do my numbers on things a bit more, and be a little more forceful [in price negotiations with pack houses] in terms of what returns we need to make things work." David, Grower "…When we're pricing for our customers, we actually include a crop-loss figure. So with carrots we use one [year] in seven. With beans we use one in five. So we're talking about complete crop loss due to weather conditions. [The supermarkets] don't always like that, but … we need to include that. It's real…. that's not always treated in a good light by our customers. They don't actually see the value or the relevance, you know? [But] if we're going to sit there and talk about being sustainable in the future, you do have to talk about it." Mark, Pack house Manager
Seek to establish additional large volume customers (particularly overseas) to reduce reliance on Australian retailers	"…there's a determination by most of the producers to look overseas for a second or third major customer … in addition to the one or two [Australian supermarkets] that they're supplying at the moment. It's out of frustration with those one or two customers that they're not being responsive to our requirements..." David, Grower "We're going to actively seek another large customer in Asia, with everything we've got… because we see that as being a way out of the mess, is to have another option that is very real and a large scale customer." Mark, Pack house Manager
Refocus business and supply chain towards higher return export markets, drawing on significantly enhanced levels of collaboration between wholesale agents and grower-suppliers	"[The Australian supermarkets] have got far too much power, but I believe in the way that we have taken our business now…[by] working close with growers to get the required product for the export market, you won't need the chain stores ... The Asian customers will pay the money… if the product meets the price ... So with some of our mango farmers, we're working very close with [them] to pack that product because the difference could be $10 more per tray than the domestic market will get." Alex, Wholesaler
Adapt business strategies or models	"So my risk management tool is to lease the farm out to a larger grower who has capacity to take that risk …. And if we were to come back we've got to be doing something very different to what we're doing now…." John, Grower "Fundamentally, [in shifting our business focus to high quality produce for specialist green grocers]... I'm trying to grow products that go up against the chains. So that the regional shops … that are trying to put good products on the shelves and get customers in and have a passion for the industry, come in and look at my gear in the market and go, 'Yeah, that'll go well on my shelf' – that's what I want." Michael, Grower-packer

Source: Author's analysis, drawing from interviewees' accounts

Simon, spokesperson for Supermarket B, shared his company's perspective on the constraints to increasing prices:

> Price and value is very [much] at the forefront of the customers' mind. Even more so now than in the past, people are looking for value and you see sales drop off as prices go up. There are thresholds for different products. So, when certain products get to certain price points, sales will really drop off or they'll really accelerate … sometimes it's not as simple as putting up prices.

The relentless pressure from retailers to drive down costs throughout the supply chain also affects businesses in the freight and logistics segments. Tony, owner of a freight company, identified a significant barrier to achieving more sustainable pricing arrangements was an unwillingness of players in the upstream segments of the supply system to act collectively and consistently to pursue improved payments for products or services:

> At the end of the day the transport [industry] can stop the nation if they really wanted to, but … they don't want to bind together because they're competition and they hate each other...so we don't … if we really wanted to [we would] bind together … and get prices so we can actually survive [but] it'll never happen … and farmers are exactly the same.

Accordingly, amongst some interviewees there was little confidence that improved pricing arrangements could be negotiated or maintained in fresh produce supply chains in the long term, and some growers were questioning their, or their children's, future in the industry.

Efforts to seek a more equitable distribution of risk in supply chains

The next significant response that emerged from the interviews was that recent natural disasters had caused some actors to question the distribution of climate risk in supply chains. Some interviewees expressed frustration that although retailers could share climate risks with suppliers, they generally chose not to. Freight company manager, Scott, for example, pointed out that retailers' tendency to discourage their customers from accepting superficially damaged fruit actively undermines opportunities to improve the distribution of climate risks within the supply chain:

> Say if [Cyclone Marcia] had hit Gayndah and Mundubbera and there's a lot class two [citrus fruit] on the marketplace but [the supermarkets] could still buy class one. Would they drop their standards and take in class two to help the growers? I'd say they wouldn't … because that's not what they believe their consumers want –

> because they haven't sold to the consumer the idea of 'just because the skin's damaged, it's still good inside and by buying this you're actually helping the poor buggers get back on their feet for next year and the year after.'

Others focused on the sharing of risk between pack houses and the growers who supply them. Recent extreme weather events, including heat waves and recurrent floods, highlighted that while growers mostly benefit from their relationship with pack houses, the supply arrangements do leave growers exposed to climate risks while pack houses are often unaffected or minimally impacted. John, a supplier to a number of pack houses, explained the difference between the risks he carried as a grower compared to those experienced by a pack house:

> Then there's another problem: risk. So, for example … our window for [harvesting] sweet corn is this and this in the whole year. So if we get a storm on harvest day we've lost out… we're in that cycle. Like, [the harvester for the pack house is] in Kalbar today, they're here next week, they're in lower Lockyer the week after. So that's when we plant. Get a storm at harvest, we've lost it. So for us that's our entire income for that period. Whereas for the … packer he's not feeling it because tomorrow it's the next crop. They never stop harvesting.

Growers, John and David, indicated that in some pack house-based supply chains, suppliers were raising their dissatisfaction regarding their exposure to climate risks and seeking changes that would enable some sharing of risks. John commented that "the growers have said, well, we're not growing [for you] anymore unless you change the rules." Unfortunately, little further evidence of the nature of these discussions or their outcomes was gathered in the study. John and David's accounts do suggest, however, there is a growing awareness amongst some actors of the need to achieve more equitable distribution of climate risks in fresh produce supply chains and preliminary efforts towards this, particularly between grower-suppliers and pack houses. Further research will be needed to gather additional evidence to support this finding.

Emerging questions regarding the role of government

The interviews revealed a final important finding: the absence of a proactive contribution from government towards effective responses to climate impacts and risks in fresh produce supply chains. Interviewees' accounts indicate that the State Government did play three key roles following the recent natural disasters in south-east Queensland. The first was to mobilise a clean-up crew to restore the Brisbane Markets site, enabling the State's

fruit and vegetable wholesale hub to re-open within three business days of the 2011 flood. The second was the provision of financial assistance to (eligible) farm businesses to support their recovery from disaster events, and the third was to plan and resource repairs to transport infrastructure, in particular highways and rural roads and bridges. While some noted their appreciation of government's interventions and assistance, the interviews identified significant short-comings in government's actions, policies and regulatory frameworks, indicating there are opportunities for the state to contribute more directly to improved governance of climate risk in fresh produce supply chains.

Research participants felt that, rather than providing a supportive environment for farming and food industries, government's policy and regulatory frameworks generate significant costs in most segments of the supply chain. Interviewees highlighted the high costs associated with government's workplace health and safety requirements, electricity pricing frameworks and other regulations, and wholesalers also expressed frustration that government services, such as quarantine inspection, do little to facilitate efficient and cost-competitive trade, particularly for exporters. Upstream supply chain members argued that these government-driven costs of business exacerbated the challenge of achieving adequate profit margins and building financial reserves and, therefore, contributed to their poor capacity for disaster recovery and resilience.

Interviews also revealed dissatisfaction with the Queensland and Australian Governments' natural disaster relief and recovery arrangements (NDRRA), in particular the eligibility criteria, application process and targeting of assistance measures for disaster-affected businesses. Stuart, a large grower-packer, questioned the 'one-size-fits-all' approach to recovery grants:

> To put that into perspective ... my neighbour has got a 40-acre block and he was eligible for the $25,000 grant for flood recovery/disaster management. We're farming owned and leasehold lands, 3000 acres, and we're eligible to get $25,000. I mean, this business turns over $20 million a year … I shouldn't sound ungrateful, but the scale of things… didn't match up.

Growers also observed that grants or low interest loans were made available to farm businesses many considered unviable, including growers who frequently under-price their produce and were willing to sacrifice profitability to at least maintain cash flow. Further, despite the severe financial hardship experienced by businesses in other segments of the supply system, government assistance was limited largely to farm businesses. Freight

companies, in particular, identified that apart from being ineligible for NDRRA grants, governments offered no concessions to them at all:

> We don't get any compensation or anything … if you're a farmer you get all these flood benefits, where we're actually in the middle of the whole merry-go-round and we get absolutely nothing – Tony, freight company owner.

> The governments don't come along and go “oh, sorry … I know you were flood-bound here for three months but I'll still take my registration off you even though you couldn't move the trucks”. Like that's where they should give companies some relief – Rob, freight company manager.

Finally, interviewees argued that governments were failing to make infrastructure more robust to natural disasters in the future and had simply made repairs to roads and bridges without consulting with stakeholders, engaging in strategic planning or investing in improvements. Tony, a freight company owner, commented,

> they need four major corridors and physically have a look at where the worst flood is and build the road above that, if they don't want to have any more devastation.

He felt, however, that budgetary constraints combined with the extent of damage caused by recent floods posed a major barrier to achieving significant improvements to Queensland’s transport infrastructure:

> What they're actually doing now I wouldn't say that they're gearing [the road network] up for anything, because they're only patching the existing roads or the existing infrastructures they've got… like they got their hands in that many pies around fixing this, fixing that, fixing that, but they're not doing it properly … It's like a patchwork quilt.

Another barrier was the apparent lack of communication between key food industry stakeholders and governments regarding opportunities to improve transport infrastructure. While Simon felt it may not be appropriate for his company (Supermarket B) to be involved in such discussions, freight industry actors believed that government consultation processes tended to be token gestures. Tony described government decision-making as a closed process:

> Well behind the scenes we don't know what roads are putting in place and what [governments are] about to do … Now what they've got behind closed doors that me or you and anybody else can't see, we'll never know.

The study's findings suggest that governments have done little to strategically engage with supply chain members to support effective responses to flood impacts and continuing climate risks in the fresh produce supply system. The interviews indicate that the state's role has been limited to assisting responsiveness to disasters in food supply chains, with few tangible contributions to supporting the effective governance of climate risk or adaptation to emerging climate risks in the food system. Research participants' insights, however, point to significant opportunities for the state to engage with food industry actors on how climate risks could be more effectively managed in food systems, including options to adjust policy and regulatory frameworks to become more cost-efficient, design more effective and more targeted natural disaster relief and recovery arrangements, and invest more strategically in transport infrastructure.

Prospects for adaptation to emerging climate risks

Following recent flood events, research participants described various adjustments made within their own businesses that reflect the tendency in fresh produce supply chains towards individualised governance of climate risks. The interviews also identified, however, responses that open opportunities for collective action towards more effective management of climate risks within the chain. The strengthened resolve amongst a number of interviewees to negotiate higher returns for produce, to establish new markets, or to adjust risk sharing between growers and pack houses may be catalysing a clearer dialogue amongst supply chain actors regarding the distribution of climate risks and the pricing structures necessary to account for these risks. Yet the price sensitivity of Australian consumers described by Simon (Supermarket B) and the intense competition between Australian retailers pose significant constraints on these efforts. The strong view, shared by many growers, packers and wholesalers engaged in the research, that establishing large scale customers in overseas markets was the key to achieving higher returns on fresh produce indicates that these actors see an increased engagement in global-scale supply chains as an important aspect of building their financial capacity to cope with climate risk. While a number of research participants mentioned their appreciation of the re-emergence of farmers markets and local food networks, only one grower-packer involved in the research had sought to re-align their business to target local or specialist green grocers as an opportunity to achieve price premiums. These findings contrast significantly with agri-food literatures that emphasise how re-spacing, re-localising and reconnecting agri-food supply chains could address many socio-economic and

environmental failings in contemporary food system (see for example Hinrichs, 2013, Kirwan and Maye, 2013, Marsden, 2012, Winter, 2006).

The view amongst research participants that recent extreme weather events have reinforced trends towards diversified production sites supports earlier findings in wine, peanut and seafood supply chains that relocation, expansion or diversification of production or harvesting sites were common responses to shifting climate patterns (Galbreath, 2014, Lim-Camacho et al., 2015, Marshall et al., 2014). Interestingly, while governance arrangements or adjustments to existing eco-certification schemes were identified as playing a potential role in adaptation to changing climate risks in wine and seafood supply chains (Galbreath, 2014, Lim-Camacho et al., 2015), the option of incorporating climate risk management procedures into fresh produce certification schemes was not raised by any participants in this study. Finally, while the study identified dissatisfaction amongst supply chain members regarding governments' interventions and policy and regulatory frameworks, few interviewees directly articulated that the state should play a stronger role in supporting adaptation to emerging climate risks in the supply chain. This may reflect the strong culture and practice of private governance arrangements within fresh produce supply chains.

Conclusions

The findings presented in this chapter help to address a number of key gaps in the literature identified in chapter two. First, that in spite of a strong emphasis in business and logistics literatures on risk management in supply chains and on supply chain governance in agri-food research, little is known of the ways in which climate risks are governed in food supply chains. Second, a number of researchers have noted the paucity of empirical studies regarding business, industry and supply chain level efforts to respond to climate impacts or to adapt to climate change (Galbreath, 2014, Lim-Camacho et al., 2015, Linnenluecke et al., 2013) . This study offers important insights into both the governance of climate risks in fresh produce supply chains and how actors' responses to recent natural disasters may influence climate risk governance and adaptation to climate change in the future.

The management of risk as a core function of supply chains is highlighted in the literature and is argued to require inter-organisational effort, cooperation and mutuality (Juttner, 2005, Pettit et al., 2010). This study demonstrates that in market and modular styles of

fresh produce supply chains there is a lack of mutuality and cooperation and significant structural and cultural barriers to addressing climate risks through collective efforts between supply chain members. The study has also found, however, that the emergence of new supply chain intermediaries - the packer-marketer companies – are helping to establish relational governance arrangements in the fresh produce supply system that enable climate risk to be governed in more collaborative ways and that support a more even distribution of decision-making power, profit and risk in the supply chain. The findings also show that recent disaster experiences have motivated some supply chain actors, particularly those in market and modular supply chains, to seek improved prices and profit margins and opportunities to better share climate risks between supply chain members. The study has found, however, that supermarket practices and competitive strategies pose significant barriers to efforts to address the distribution and management of climate risks in supply chains, even in packer-marketer facilitated chains. Actors' experiences of these barriers are leading many to seek an increased focus on developing export markets and engage in global supply chains as a means to improve profit margins and enhance their capacity to recover from climate impacts in the future. Finally, the study has shown that the state is largely absent in the governance of climate risk in the fresh produce supply system. While government interventions support responsiveness in the supply chain following natural disaster events, the findings of this study suggest that the state could more directly engage with supply chain actors to identify opportunities to improve transport infrastructure as well as develop a more supportive policy and regulatory environment for the food industry. In the final chapter, the findings of this study will be considered in light of the attributes of supply chain resilience identified in chapter three. From this, conclusions will be drawn regarding the prospects for cultivating resilience to natural disasters and escalating climate risks in fresh produce supply chains.

Chapter seven: Prospects for cultivating climate change resilience in agri-food systems

Introduction

This concluding chapter addresses the final question of the research: what are the prospects for resilience in fresh produce supply chains in the context of climate change and what implications are there for food security? The analysis draws on the findings presented in both results chapters and considers them through the lens of the attributes of agri-food supply chain resilience proposed in chapter three. The analysis also reflects on two important themes from the literature discussed in chapter two. The first is that the supermarketised food system lacks resilience and is becoming increasingly vulnerable to disruption with a diminishing capacity to address its weakness (Lawrence and Dixon, 2015, Marsden, 2013, Sage, 2013). The second is the need for a more direct involvement of the state to support climate adaptation efforts within food industries and supply chains (Fleming et al., 2014, Galbreath, 2014, Lim-Camacho et al., 2015, Linnenluecke et al., 2013). It is argued in this chapter that the study has revealed both enabling and constraining influences on supply chain resilience to climate risks but that, on balance, the identified constraints may contribute further threats to Australia's food security. The study's findings, however, also point to opportunities to support the development of more relational supply chains and to engage both the state and consumers in building supply chain resilience to climate risks.

Next, the theoretical contributions that emerge from this research are discussed. The first is its contribution to developing a deeper understanding of the role of social agents and institutions in addressing food security and, more specifically, the social dimensions of supply chains and their role in addressing climate risk - priority research needs identified in chapters two and three (Ericksen, 2008, Johnson et al., 2013, Juttner, 2005, Peck, 2006a). The second, is the contribution this study has made to conceptualising resilience in the context of food systems facing escalating threats from climate change. It is argued that bringing a stronger focus on social aspects of resilience confirms the need to further theorise the critical role of individual and collective agency and also highlights the value of bringing a governance perspective to the study of resilience to climate risks in the agri-food system. The chapter concludes by noting the study's limitations and opportunities for further research.

Reflections on resilience to natural disasters and climate risks in fresh produce supply chains

Drawing together the study's findings regarding actors' risk constructs, approaches to risk governance, the impacts of recent disasters, and actors' responses to them provides insights into the prospects for developing resilience in fresh produce supply chains to climate risks and more frequent natural disasters. The conceptual framework for this thesis, developed in chapter three, proposed a suite of attributes that would underpin food supply chain resilience to escalating climate risks. The attributes (detailed in Table 3.2) include a shared commitment amongst supply chain members to proactive risk management; planning; collaboration; learning; adaptability; connectivity; an equitable distribution of risks and rewards; and a capacity to accumulate financial and other reserves. Supply chains with these attributes are theorised to have an enhanced capacity to cope with shocks and stresses and to thrive in the face of disruptions; an ability to use supply chain disruptions to implement innovation and renewal that builds competitive advantage; and a capacity to become increasingly well-adapted to changing environments and emerging climate risks. These theoretical attributes and outcomes of resilience provide a lens through which to consider the empirical findings of this study.

The analysis of responses to recent disaster events presented in chapter six indicates that actors in most fresh produce supply chains can be highly adaptable in the short term, however, drawing together findings from across the thesis, it is apparent that few actors demonstrate a capacity for adaptability over longer time scales. The study's findings suggest that when extreme weather events disrupt supply chains, members tend to respond rapidly and apply significant flexibility and improvisation, particularly in sourcing and transport. Following the event, there is evidence that individual businesses apply lessons learnt from the experience to adjust their own operations and practices. There was little evidence, however, of collective responses to these events. The results indicated that supply chain partners did not seek opportunities to collectively discuss lessons learned from floods, develop shared risk knowledge or identify supply chain-level management responses. Particularly in the market and modular supply chains, which were described as loosely connected and often exploitative, members had little or no interest in, or opportunity to, work collaboratively, develop shared goals or plans, collectively anticipate risks, or pursue a structured approach to risk management amongst supply chain partners.

Instead, the study found that in these chains, the governance of climate risks was largely individualised, reactive and opportunistic.

This study has also shown that in these supply chains, risks and rewards (in the form of returns or profits) are very unevenly distributed amongst members. The results presented in chapter five demonstrate that vegetable growers and freight companies experienced the most significant and long-lasting impacts from recent flood events, linked to a higher spatial and financial exposure to risks relative to other supply chain members. For growers, in particular, rapidly recurring floods had led to accumulating impacts. At the same time, these actors struggle with tight profit margins linked to continual pressure from wholesalers and retailers to supply produce or services at the lowest possible price. Accordingly, there is also a very limited capacity amongst businesses in the upstream segments of fresh produce supply chains to accumulate financial reserves. The findings outlined in chapter six demonstrates that following recent flood events, efforts are being made in some modular and market supply chains to address the distribution of risk and reward. However, structural factors in domestic markets, particularly the market power of supermarkets, the highly competitive retail environment, and the price sensitivity of Australian consumers, are likely to significantly constrain the prospects of sustaining improvements over the long term. The findings from this study, therefore, suggest that businesses in market and modular style supply chains have limited opportunities to build their capabilities or invest in innovation that would support their capacity for adaptability over the longer term. It is concluded, then, that in spite of evidence of short-term adaptability and learning in market and modular supply chains, there is little or no effort to address disaster or climate risks in the inter-organisational domain, and opportunities to collectively develop attributes of supply chain resilience are limited.

In contrast, relational-style supply chains that are facilitated through packer-marketers exhibited a greater number of resilience attributes. Actors involved in these chains described how they shared some common goals with their supply chain partners and were endeavouring to collectively pursue a structured and integrated approach to managing anticipated climate risks. The resilience attribute most strongly present in relational style supply chains was the degree of collaboration, including open communication amongst actors in each segment, trust-based relationships, and a capacity for each partner to contribute to negotiations and decision-making. Actors in packer-marketer based supply chains also recounted an emphasis on investing in innovation, which indicates these chains will have a greater capacity for adaptability over the long term. Importantly, in these

chains, both risk and reward (profit) appear to be more evenly shared than in market or modular supply chains. This is achieved through packer-marketer companies facilitating higher profit margins for their suppliers based on a stronger guarantee to retailers of consistent quality and reliability of supply. Within these supply chains, the results also demonstrate that packer-marketers and supermarkets are co-investing in the development of more sophisticated production systems, including protected cropping – an example of lead firms directly investing in smaller suppliers (Johnson et al., 2013). There was evidence, however, of uncertainty amongst grower-suppliers and packer-marketers of the long-term commitment of supermarkets to these arrangements. The most significant barriers to enhancing resilience attributes in packer-marketer facilitated supply chains - in particular those of planning, collaboration, collective learning and connectivity - lay in the tendency for supermarkets to cycle personnel through organisational positions and an unwillingness from supermarkets to make firm, formal or long term commitments with suppliers. The relentless pressure to keep retail prices of fresh produce as low as possible also poses a constraint on profit margins for all supply chain partners and dampens their capacity to invest in innovation.

Beyond the resilience attributes identified in the theoretical framework, the results of this study reveal two aspects of social agency that exert a significant influence on the extent to which fresh produce supply chains build resilience. These were supply chain actors' perceptions and constructs regarding climate risk, and the approach actors' brought to risk management. As seen in chapter five, supply chain actors' risk constructs influenced whether risks were normalised or problematised. The findings presented in chapter six showed that supply chain actors bought very different approaches to managing climate risks, with some demonstrating a more individualised, reactive or opportunistic style while others pursued more proactive and/or collaborative approaches. These two aspects of social agency can be seen in the results of this study to interplay in varied ways. For example, Peter and Liz (grower-packers involved with a packer-marketer based supply chain) constructed climate risk as increasing and influenced by both climate variability and climate change. Their problematisation of climate risk and preference for proactive risk management contributed to their drive to find supply chain partners willing to work collaboratively towards shared goals. In contrast, George (a packer-marketer) normalised climate risks through the climate variability narrative, yet saw a need for a proactive and collaborative approach to more effectively manage those risks. Similarly, Mark (a grower and pack house manager) strongly held to the climate variability narrative, though pursued

a proactive strategy to incorporate a crop loss margin in pricing negotiations with retailers. Others, such as Tim, who followed the collective construct of climate risk as a normal function of climate variability, brought an individualised and opportunistic approached to climate risk management. Finally, Simon (from Supermarket B), considered that climate change was driving an increase in climate risks, but implemented supply chain strategies that reinforced individualised and reactive governance of climate risks.

The study's findings indicate that where climate risk has been both problematised and proactively and collectively managed in supply chains, members appear to experience less severe impacts from extreme weather events and report a stronger capacity to recover from the impacts they do experience due to an ability to draw on financial reserves and support from chain partners. Peter and Liz's accounts offer an example of this. It is noteworthy that these growers did not need to adjust their management strategies or supply chain governance arrangements following the recent floods. In contrast, in supply chains where climate risk has been normalised and reactively and individually managed, upstream members of the chain were exposed to greater risks, reported more severe impacts from extreme weather events, and experienced a poorer capacity to recover from impacts. This is seen in the accounts of growers such as Kate and Stuart, freight companies (in particular, Rob and Tony) and wholesalers such as Tim. For growers such as David or Michael, the recent flood events had catalysed efforts to seek improved profit margins that would enable them to build financial reserves and/or change the distribution of risks in the chain. Their responses to recent recurrent floods may result in their supply chains becoming more relational. These observations support the arguments made by social resilience researchers that proactive agency is an essential factor in enabling resilience (Davidson, 2010, Magis, 2010, Skerratt, 2013), a point that will be discussed further in the next section.

What conclusions, then, can be drawn regarding the prospects for resilience in fresh produce supply chains facing escalating climate risks? Leading agri-food scholars claim that the contemporary, globalised, supermarketised food system lacks resilience and is not well structured to cope with climate change (Lawrence et al., 2013, Marsden, 2013, Sage, 2013). Analysing both long and short food supply chains in Australia following recent natural disasters, Smith and colleagues (2016) similarly concluded that neither could be characterised as resilient. The results of this study confirm that under the governance arrangements operating in many fresh produce supply chains in Queensland, few of the theorised attributes of resilience to climate risk were evident and that outcomes of supply

chain resilience were not being achieved in most cases. This study concludes that in market and modular styles of fresh produce supply chains, the prospects of developing resilience to escalating climate risks, and indeed to the broader set of pressures outlined in the literature (Lawrence et al., 2013, Marsden, 2013, Sage, 2013), are poor. This is particularly so where supply chain actors draw on the climate variability narrative to normalise climate risks and where risks continue to be governed in individualised, reactive and opportunistic ways in the chain.

Yet, this study also demonstrates that where supply chain actors have problematised climate risks and sought to establish more relational governance arrangements that facilitate cooperation, shared decision-making and proactive, collaborative risk management, the prospects for enhancing resilience in the face of climate change are much stronger. Specifically, the research has shown that new supply chain intermediaries – the packer-marketer companies – who have emerged, in part, due to the failings of traditional wholesale agents, play an integral role in nurturing resilience attributes. In particular, packer-marketers can facilitate stronger connectivity between suppliers and supermarkets and provide a clearer focus on strategic planning. They also exhibit a stronger emphasis on collaboration and dialogue, the development of products that generate a higher profit margin in the supermarket, and afford significantly greater opportunities to more evenly distribute both profits and risks amongst supply chain members. Grower suppliers involved in packer-marketer facilitated supply chains reported earning higher profit margins and a showed a capacity to build financial reserves. Marsden (2013) suggests that solutions to the problems of resilience and sustainability in the UK food system are likely to arise from the networked agency of actors operating at the niches of the mainstream supply chains, creating greater spatial embeddedness and introducing styles of governance that support innovation and transformations. This study, in contrast, indicates that in the Australian context, it is actors within the mainstream system who are applying their networked agency to tackle risks arising from climate variability and change, and who are shifting governance arrangements towards more cooperative models that support innovation. Interestingly, their approach is not based on the development of more spatially embedded supply networks, but an increased emphasis on national scale networks[18]. The findings do confirm, though, that networked agency and alternate governance arrangements are playing critical roles in challenging "'business as usual'

[18] Which, in turn, adds further urgency to the need to address identified weaknesses within Australia's national transport infrastructure.

logics" and "'locked in' paradigms associated with 'first-order' governance" (Marsden, 2013, p. 124). As noted, however, supermarket practices and the hyper-competitive retail market restrict the opportunities to fully develop risk governance and resilience, even within these cooperative supply chain arrangements.

Implications for food security and food policy in Australia

This study has identified significant constraints to cultivating resilience to climate risks in fresh produce supply chains. As noted in chapter one, a number of threats to national food security have been identified in Australia. The findings of this study suggest that the limited capacity of fresh produce supply chain members to adapt to more frequent and intense severe weather events should be recognised as adding a further threat to Australia's food security. This, in turn, suggests that neoliberal principles that encourage the private governance of climate risks in food systems should be challenged.

As noted in chapter three, matters of significant public risk are argued to be more effectively managed under an inclusive risk governance framework that engages a wide set of state, private and civil actors in risk framing, analysis and decision making (Klinke and Renn, 2012, Rosa et al., 2013, van Asselt and Renn, 2011). This study demonstrates that actors in fresh produce supply chains recognise that both governments and consumers have an important influence on their capacity to account for and manage the risks of extreme weather events and natural disasters. As outlined in chapter six, following recent floods in south-east Queensland, a number of research participants expressed their dissatisfaction with the inadequate contributions made by governments to support their recovery or to enhance supply chain resilience. This reflects findings from other studies that climate adaptation within industries and supply chains may be impeded by inadequate policy and regulatory frameworks (Linnenluecke et al., 2013), and would be supported by greater interaction between industry and government to inform an iterative policy and program development process (Fleming et al., 2014). Recent research has identified specific actions that governments can take to support adaptation to emerging climate risks in the agri-food sector, including the maintenance of robust transport and other critical infrastructures, public investment in research and development, provision of regional-scale climate projections or support for insurance schemes (Galbreath, 2014, Hill and Wiener, 2012, Lim-Camacho et al., 2015, Linnenluecke et al., 2013). Similarly, Marsden notes the emerging recognition amongst actors in the UK that "…the established relations between government and the private food sector needed to change" and that "new alliances and more reflexive arrangements need to be forged" (2013, p.131). He concluded that

governments must inevitably be drawn back in to participate in the development of a more sustainable and resilient food system. Reflecting on lessons learned from the Queensland floods of 2011, MacMahon and colleagues (2015, p. 389) note that while reactive strategies can meet immediate food supply needs, solutions to wider and longer-term food security issues will "need to engage the creativity of stakeholders throughout the supply chain, encouraging diversity and ensuring that business goals align with goals of food security and community well-being".

The results of this study confirm these positions, and lead to the conclusion that there is a strong rationale for the formal establishment of a risk governance process for climate risks in the food system in which both state and civil actors play a more active role. Bringing a risk governance approach to climate risk and resilience in fresh produce supply chains could further enhance and extend the improvements being achieved in packer-marketer facilitated chains. Further, it offers a framework in which governments and food industry stakeholders could identify needs and develop responses that support both supply chain resilience to changing climate risks and higher level goals of food security. A risk governance approach also offers the opportunity to more directly engage consumers in the challenges of building food system resilience to climate change. A number of participants in this research expressed frustration that consumers' demands for inexpensive fresh produce ultimately drove the constraints on profit margins experienced by all members of the supply chain. While the links between consumers' purchasing and consumption decisions and climate adaptation in the food industry is an emerging area of research (Lim-Camacho et al., 2016), agri-food scholars have debated the potential influence that "ethical consumption" and "citizen-consumers" could have on catalysing food system transitions (Johnston and Szabo, 2011, p. 303). Johnston and Szabo found that "reflexive consumer practices offer the prospect of thoughtful, politicised engagement with the food system … where people think beyond individual self-interest" and "reflect on the needs of other people" (2011, p. 315). They also note, however, that consumers often perceive themselves "as individuals confronting a food system behemoth" rather than as "part of a larger collective that could petition the state to make changes to the food system" (2011, p. 316). Others go further, arguing that "individualised consumer approaches to environmental protection is part of, and potentially supports, a neoliberal culture that undermines a collective sense of civic responsibility and state regulation of ecological issues" (Szasz, 2007 in Johnston and Szabo, 2011, p. 317). A risk governance approach, therefore, may offer an alternative to relying on reflexive decision making by individuals 'in-

store' – providing, instead, an opportunity for consumer representative groups to participate in a different level of discourse and decision-making; offering a new space in which civil society could engage in solutions to complex problems of food system resilience and food security. Carolan (2011, p. 3) has warned that a food system geared towards delivering cheap food encourages society to discount the physiological, cultural, economic, and political values of food; he calls for a shift in thinking towards food "affordability" and pursuit of a food system that gives people, communities and society the capability to develop and enhance their overall wellbeing. Consumer engagement in a climate risk governance process could help build awareness that, in the context of climate change, cheap food is also unreliable food and that there is value in ensuring that food prices include a disaster risk margin and reflect the true costs of building resilience to climate risks in supply chains.

Contribution to theory

This study has made three key contributions to theory in the agri-food studies and climate adaptation fields. It has demonstrated the value of conceptualising supply chains as social institutions with key roles in addressing climate risks in food systems. It has contributed to the conceptual development of resilience in the context of food systems and agri-food supply chains affected by climate change. Finally, it has shown important connections between the concepts of supply chain governance, risk governance and resilience. Each of these contributions is discussed, in turn, below, and finally, some reflections are offered regarding the value of a critical realist perspective for this study.

In proposing a framework to support research regarding food systems in the context of global environmental change, Ericksen (2008, p. 243) notes that "institutions play a key role in mediating between the social and ecological processes and resources." She argues that to protect food security and build food system resilience to global environmental change requires identifying the "key institutions with which to work" (Ericksen, 2008, p. 244) and highlights institutional processes and food system governance as research priorities. In this study, I have conceptualised agri-food supply chains as social institutions and brought a sociological perspective to the study of food supply chains affected by natural disasters and climate change. The findings of this study enhance knowledge of the social actors within the supply chain, the relations between them, how climate risks are perceived and socially constructed (both individually and collectively), how climate risks are governed, and how this (and other structural factors) influence how actors respond to

disaster events and future climate risks. In doing so, this study has demonstrated that supply chains *are* a key social institution within the food system and a critical site for decision-making regarding climate risk. The research has shown that supply chains, as social institutions, play a powerful role in shaping how, and whether, adaptation to climate change occurs within the agri-food system – with significant implications for food security. In considering fresh produce supply chains as social institutions (and by applying a critical realist perspective), this research has provided insights into the important interplays between supply chain relations and governance, wider food system structures, and the agency of individuals in the chain – as well as the implications these have for the prospects for enhancing resilience in supply chains to escalating climate risks. Future studies of resilience and climate adaptation in food systems and supply chains would benefit from applying this perspective.

A second contribution this study has made is to advance the application of resilience theories in food systems research. While a body of literature regarding food system resilience is emerging (Hendrickson, 2015, Rotz and Fraser, 2015, Tendall et al., 2015), there has been limited research focused on agri-food supply chain resilience in the context of natural disasters or climate change (Singh-Peterson and Lawrence, 2015, Smith and Lawrence, 2014, Smith et al., 2016). This thesis contributes to this emerging field by theorising how actors in food supply chains might develop resilience to climate risks that are escalating due to climate change and, in particular, to more frequent and intense extreme weather events. Foundational work by Smith and colleagues (2016) found that scale, diversity, responsiveness and cohesion contributed to resilience in long and short agri-food supply chains in the immediate period following a natural disaster event. Building on this work and expanding its scope to consider, more broadly, supply chains facing climate change-driven risks, I have proposed a set of eight attributes beneficial for resilience. The results of this study suggest that all of the proposed attributes are relevant and worthy of further empirical investigation. In particular, however, the findings indicate that key factors in fresh produce supply chains that demonstrated a higher level of resilience to natural disasters and climate risks were a shared commitment to the proactive management of risks, efforts to build more collaborative supply chain partnerships, and an emphasis on achieving a more even distribution of risks and rewards between supply chain members (which in turn facilitates accumulation of financial reserves). Underpinning each of these key factors, has been the proactive agency of actors who have recognised both the inherent problems of traditional fresh produce supply chains and the need for a

more effective approach to the management of climate risks, and who have sought to establish more cooperative supply chain arrangements to support this. This insight strongly resonates with the positions held by a number of social scientists who argue that agency is integral to resilience (Davidson, 2010, Magis, 2010, Skerratt, 2013). Davidson (2013, p.23) notes that "the forms that agency takes, and who takes them, define just if and how social institutions change" and further, that the

> exchange between structure and agency is one of the fundamental interactions within socio-ecological systems that result in emergent outcomes with direct bearing on whether a system is likely to be headed for resilience, transformation or collapse.

Magis (2010) and Skerratt (2013) argue that resilience is enhanced through the collective, purposeful and pre-emptive efforts of social agents made prior to any disturbance to a community or place, along with recognition amongst community members that there is a need to be responsive to both continuous and episodic forces of change and disruption. The results of this study confirm that resilience in agri-food supply chains to natural disasters and escalating climate risks is strongly shaped by the proactive agency of supply chain members. From this research, I conclude that social resilience theories offer utility for analysis which seeks to progress the challenge of addressing changing climate risks in the contemporary supermarketised food system, and that ongoing conceptual development could focus on exploring in more depth the role of proactive collective agency amongst supply chain members.

The third theoretical contribution made by this study is to highlight the value of bringing a governance perspective to studies of climate adaptation and resilience in food systems. For this study, an understanding of the power relations created by the wider agri-food governance system provided an important contextual frame for the research, while the influence of specific supply chain governance arrangements as characterised by Gereffi (2005) and Gereffi and Lee (2012) facilitated an analysis of the varying approaches to managing climate risks in fresh produce supply chains and actors' responses to recent disaster events. Considering the research findings through the lens of a risk governance framework (Klinke and Renn, 2012, Rosa et al., 2013, van Asselt and Renn, 2011), however, was particularly useful. Applying a risk governance perspective enabled an analysis that accounted for the duality of climate risk as real and constructed, acknowledged the highly skewed distribution of power in the supply chain and highlighted the wider set of actors who may contribute to addressing climate risks. Applied together, the concepts of risk governance and resilience provide a rounded analytical frame that

produces more nuanced insights than would have been gained from the use of either concept on its own. Folke (2006) identifies adaptive governance as an important factor in social-ecological systems resilience, and social researchers have explored the connections between adaptive governance and resilience in social contexts (Chaffin and Gunderson, 2016, Koontz et al., 2015, Seeliger and Turok, 2013). The results of this study suggest that there would be value in further conceptualising the links between risk governance and resilience. As discussed above, this study has affirmed the critical importance of proactive agency in building agri-food supply chain resilience to natural disasters and climate risks. A risk governance perspective helps address one of the identified weaknesses of dominant conceptualisations of resilience which tend to focus on reactive responses to disturbance (Skerratt, 2013). Risk governance, in contrast, places a stronger emphasis in the actions that stakeholders can take in advance of risks being actualised.

Finally, the value of a critical realist ontology and epistemology for this study is noted. To develop knowledge of the social world, a critical realist perspective directs the researcher to move beyond observations of patterns of events and, instead, aim to uncover the causal mechanisms and relations that generate social conditions. Taking this approach has been useful for exploring questions regarding how actors within the agri-food system have responded to recent natural disasters, and perceive and govern climate risks. For this research, I have taken the ontological position that food system structures, relations amongst agri-food supply chain members, and the agency of supply chain actors are each distinct entities within social reality. This has enabled the research to recognise that structures, relations and agency operate with distinct causal powers in fresh produce supply chains and to investigate how the opportunities for supply chain actors to develop resilience or pursue risk governance are shaped by the interplays between them. The findings from this study clearly demonstrate both “the stringency of structural constraints versus degrees of agential freedom” (Archer, 1998, p. 203): while many actors’ responses to climate risks and recent disaster events are strongly constrained by food system structures and the ways that governance arrangements shape supply chain relations, other actors are actively reshaping supply chain relations to enable a more strategic approach to managing climate risks.

Limitations of the research and opportunities for ongoing research

One of the limitations of this research is its empirical focus on vegetable supply chains based on production in south-east Queensland, which is acknowledged to be a narrow base from which to draw wider conclusions about agri-food system resilience to climate risks and threats to food security in Australia. Vegetable supply chains also have a number of characteristics that are particular to the fresh produce industry, and therefore, the findings of this study may not be easily translated to supply chains in the wider agri-food system. Similar research in other agri-food industries – as well as further research within the fresh produce sector – would support the development of a more comprehensive understanding of responses to escalating climate risks in the food system.

One of the key findings of this research – that a stronger engagement of state and civil actors in risk governance processes would enhance resilience to escalating climate risks in fresh produce supply chains– highlights an important empirical limitation of this research. Only direct participants in the supply chain and industry recovery personnel were involved in interviews. In order to more fully explore the current and potential roles of the state and the wider community in climate risk governance in the food system, further research should engage a wider set of stakeholders, in particular, representatives of government and civil society.

Finally, this study has posed a broad set of research questions in order to generate a foundational level of knowledge in a relatively new area of inquiry for which there is limited direct literature. There is significant scope to conduct more detailed research and deeper analysis for each of the key components of the study, that is, the implications of recurrent natural disasters on food supply chains over the medium to longer-term; the perceptions of climate change and climate risks amongst actors in food supply chains; and the governance arrangements for climate risk in supply chains. In particular, research to further theorise and empirically research resilience in the context of food systems and supply chains facing climate change would be of value. While it is well recognised amongst social scientists that risk is socially constructed, an emerging area of inquiry considers how climate risks in the context of climate change are collectively constructed within communities (Granderson, 2014). This thesis provides preliminary insights into the ways in which members of fresh produce supply chains collectively construct climate risk. As social constructs affect risk perceptions and drive responses to perceived risks, further work to investigate the collective construction of climate risks amongst food system actors is an important priority for future conceptual and empirical research.

Conclusions

This thesis has considered how escalating risks driven by climate change can be addressed within food systems and agri-food supply chains - recognising that this question demands a focus on social actors, processes and institutions. The research has focused on five areas of inquiry: what have been the impacts, and implications, of recurrent floods in south-east Queensland on fresh produce supply chains? How have actors within these chains made sense of recent flood events, and how do they construct climate risks? How are climate risks governed within these chains? How have actors responded to recent flood events and is adaptation to emerging climate risks occurring? And finally, what are the prospects for the resilience of fresh produce supply chains in the face of climate change and what implications are there for food security in Australia?

The study has revealed a number of factors that constrain resilience in supply chains. The shared narrative around climate variability amongst supply chain actors has the effect of normalising extreme weather events and attenuating perceptions of future climate risks. The uneven distribution of vulnerability to climate risks found within fresh produce supply chains has resulted in upstream businesses experiencing significant accumulating impacts which have weakened the supply system and in turn increased the vulnerability of the whole chain to future damaging weather events. The characteristics of market and modular supply chains support a tendency for climate risks to be governed in individualised, reactive and opportunistic ways, and impede opportunities to pursue collaborative governance of risks. While recent floods have catalysed efforts to achieve improved profit margins and a more even sharing of risks in market and modular chains, these improvements will be difficult to sustain within the highly competitive domestic retail environment.

The study has, however, found evidence of supply chains characterised by relational governance arrangements that exhibit a number of resilience attributes and outcomes - which suggests there are prospects for cultivating resilience to escalating climate risks in supermarket-based agri-food supply chains. The findings of this research point to a number of opportunities to support resilience-building in the food system. One significant opportunity is for food system actors to embrace more relational styles of governance in supply chains that can support a proactive and collaborative approach to addressing climate risks and more evenly distribute risks and profits within the chain. Beyond this, though, there is a critical need for the state to recognise the significant constraints to agri-food supply chain resilience and that the current model - where the governance of climate

risks is largely left as a private pursuit between market actors - poses threats to national food security. The analysis from this thesis suggests that resilience could be enhanced by adopting a risk governance approach that creates spaces for consumers, market and state actors to generate more effective ways to address climate risks and climate adaptation in the food system. Investment by the state and food industries in a participative action research project aimed at scoping this opportunity would be a useful first step. Such an approach may provide a platform to pursue adaptation to escalating climate risks in a progressive spirit – one that improves food security and also achieves greater fairness in the supermarketised food system and its supply chains.

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